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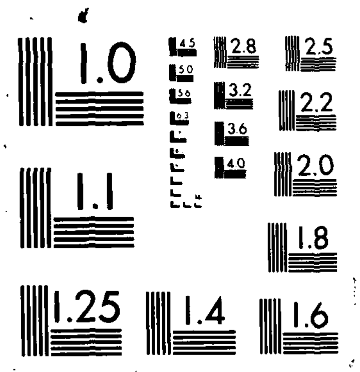
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US Army Corps of Engineers

TECHNICAL REPORT GL-87-4

GEOLOGICAL-SEISMOLOGICAL EVALUATION OF EARTHQUAKE HAZARDS AT BLACKFOOT DAM, IDAHO

by

E. L. Krinitzsky

Geotechnical Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Blackfoot Dam and Reservoir are situated in southeast Idaho in an area of active tectonism which includes recent volcanism, hot springs, and active faults. Three earthquakes were postulated for design purposes with horizontal motions as follows:

(1) Local: Distance = 0; M_S = 6.5; accel = 0.68 g, vel = 60 cm/sec, dur = 10 sec.

(2) Near Field: Distance = 30 km; M_S = 7.5; accel = 0.68 g, vel = 60 cm/sec, dur = 10 sec.

(3) Far Field: Distance = 80 km; M_S = 7.5; accel = 0.25 g, vel = 48 cm/sec, dur = 65 sec.

Accelerograms were recommended for use with these parameters.

An operating basis earthquake was based on motions for the severest shaking believed to have occurred at the damsite over the past 100 years.

The dam and reservoir are situated on a series of lava flows that could be interbedded with loess.

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PREFACE

The Waterways Experiment Station of the US Army Corps of Engineers was authorized to conduct this study by the Walla Walla District on 15 October 1982 by appropriation order FY 83 No. 96-X-4902.

The work was done and the report written by Dr. E. L. Krinitzsky, Engineering Geology and Rock Mechanics Division (EGRMD), Geotechnical Laboratory (GL). A field visit was made with Fred Miklancic and others of the Walla Walla District. Contacts were made and relevant data and opinions were obtained from Steven S. Oriel, Robert Bucknam, Charles Langer, Tony Crone, Paul Thenhaus, and David Perkins of the US Geological Survey in Denver and Golden, Colorado, and Larry Von Thun, Richard Martin and Louis Roehm of the Bureau of Reclamation in Denver. Mr. Frank K. Chang, Earthquake Engineering and Geophysics Division, GL, selected the earthquake accelerograms to accompany the recommended peak motions. Mr. Dale Barefoot, EGRMD, assisted with the compilation of data and the preparation of illustrations. The project was under the general direction of Dr. Don C. Banks, Chief, EGRMD, and Dr. William F. Marcuson III, Chief, GL.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

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GEOLOGICAL-SEISMOLOGICAL EVALUATION OF EARTHQUAKE HAZARDS AT BLACKFOOT DAM, IDAHO

PART I: INTRODUCTION

1. This study was undertaken to define the maximum credible earthquakes and their corresponding ground motions at the Blackfoot Damsite.

2. Blackfoot Dam is on the Blackfoot River which is a tributary of the Snake River in southeastern Idaho. The location of the dam and reservoir in its regional setting may be seen in Figure 1.

3. Blackfoot Dam was built in 1907-1909 and is the oldest in this part of the United States. In 1923-1924, the dam was partly removed, a concrete core wall was installed, and the dam was rebuilt 8 ft higher than previously. This is the dam which exists today. It is a combination of earth and rock fill, is 59 ft high and 369 ft long, including the spillway, and is situated on bedrock. Though the dam is a relatively small one, it impounds a reservoir (Figure 2) that is about 20 km long and 9 km in maximum breadth.

4. When Blackfoot Dam was rebuilt in 1923-1924, China Hat Dam (see Figure 2) was added at the southern end of the reservoir. China Hat Dam is an earth embankment, 23 ft in maximum height and 1113 ft long, and sits on bedrock.

5. No seismic evaluations were made previously for either of these dams. The motions developed in this report for Blackfoot Damsite can be applied equally for China Hat.

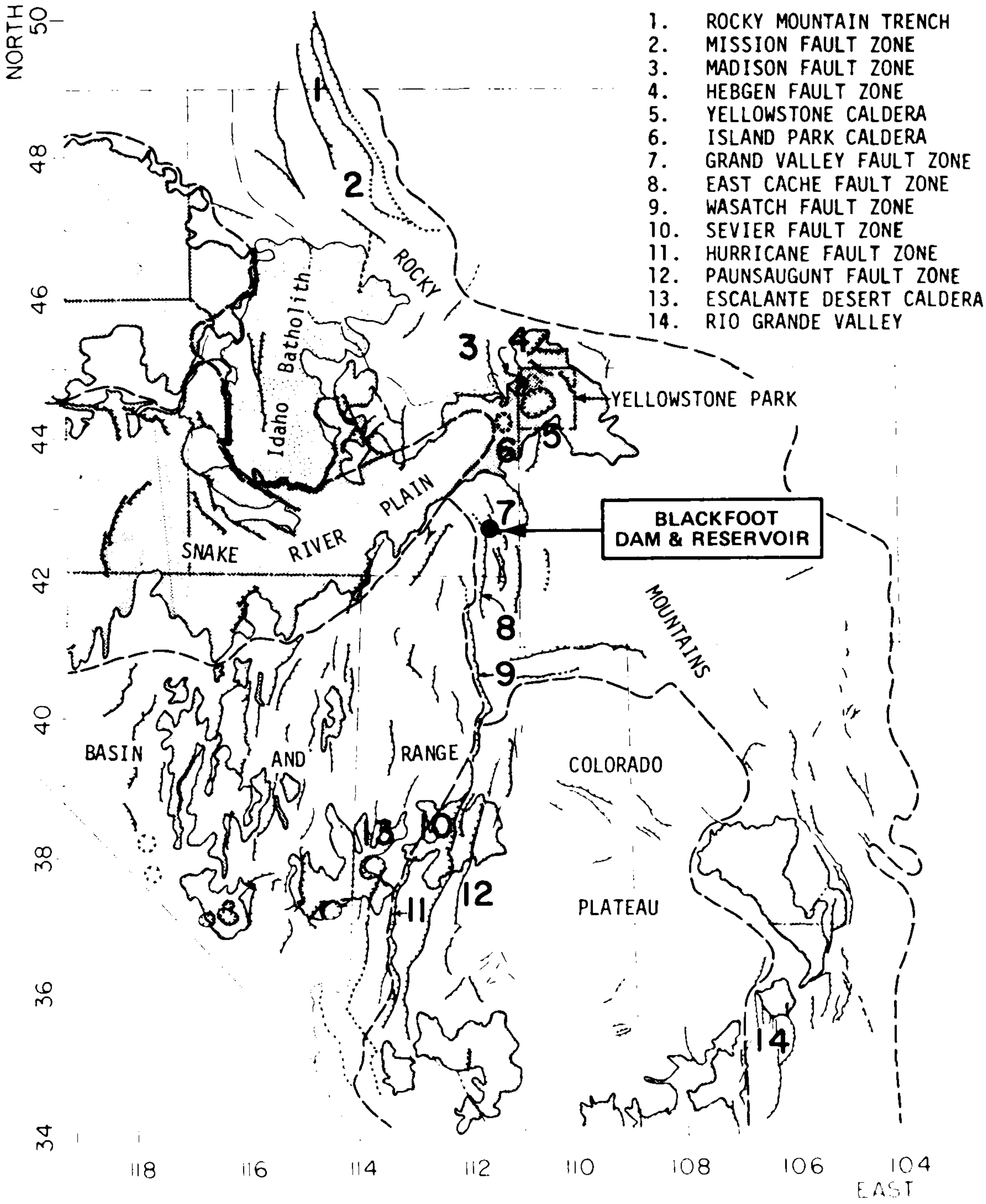


Figure 1. Principal regional geologic features.
From Smith and Sbar (1974).

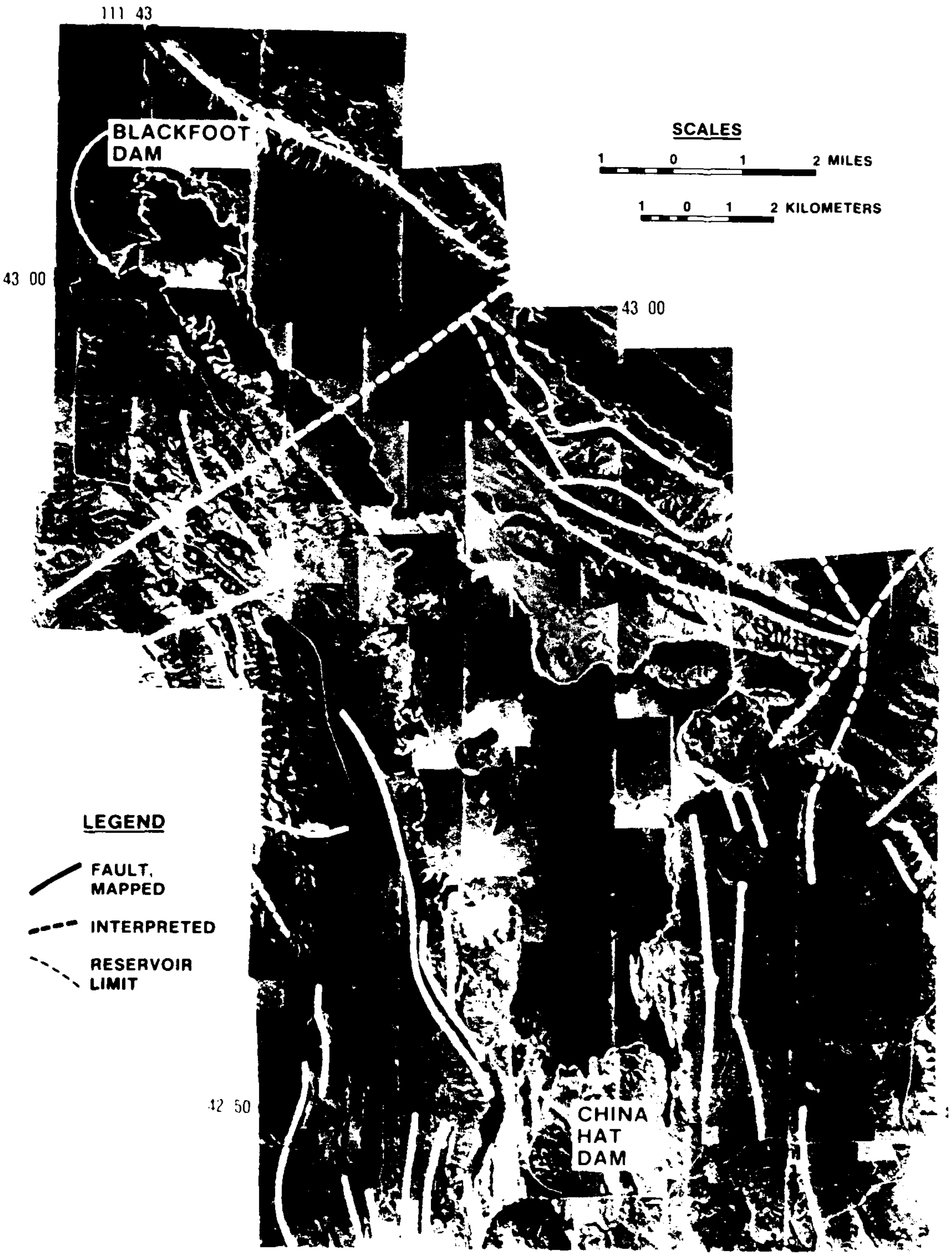


Figure 2. Airphoto mosaic of Blackfoot Reservoir and damsites. Faults are from Oriel and Platt (1980).

PART II: REGIONAL AND LOCAL GEOLOGY

Regional Geology

6. The principal geologic features in the region are shown in Figure 1, taken from Smith and Sbar (1974). Within this region there is a pronounced zone of seismicity which is known as the Intermountain Seismic Belt. This zone approximately follows the north-south boundary that separates the Basin and Range in the west from the Colorado Plateau and the Rocky Mountains to the east. This boundary is also a boundary between subplates of the North American Plate. The seismicity in this zone is greatly pronounced, as will be noted later. The Blackfoot Dam and Reservoir are situated precisely in this tectonically active zone.

7. The Idaho Batholith is a large body of intrusive igneous rocks and is bordered on the south by an extensive area of volcanic rocks in the Snake River Plain. The eastern portion of the Snake River Plain adjoins the areas of Yellowstone and Island Park calderas. The latter have resulted from geologically very recent volcanism. Blackfoot Dam is situated a short distance to the south in a zone that also includes the Grand Valley, East Cache, and Wasatch faults. These major faults are along and may be part of, the intraplate boundary which was previously cited.

Characteristics of the Snake River Plain

8. As its name implies, the Snake River Plain is large and relatively flat. In contrast, its surroundings are mountainous. Geophysical investigations indicate that the Snake River Plain has distinctive characteristics in the subsurface as well.

9. Figure 3 shows a map of Bouguer gravity anomalies, prepared by Mabey (1978), in which the lesser values predominate in the Plain as compared with the surrounding areas. Figure 4, also from Mabey (1978), shows the results of a magnetometer survey. In general, high magnetic intensity values correspond to low values for gravity. However, there is much irregularity in the magnetic values where they are at their highest. Locally, there is a small concentration of magnetic irregularities at and near the Blackfoot damsite.

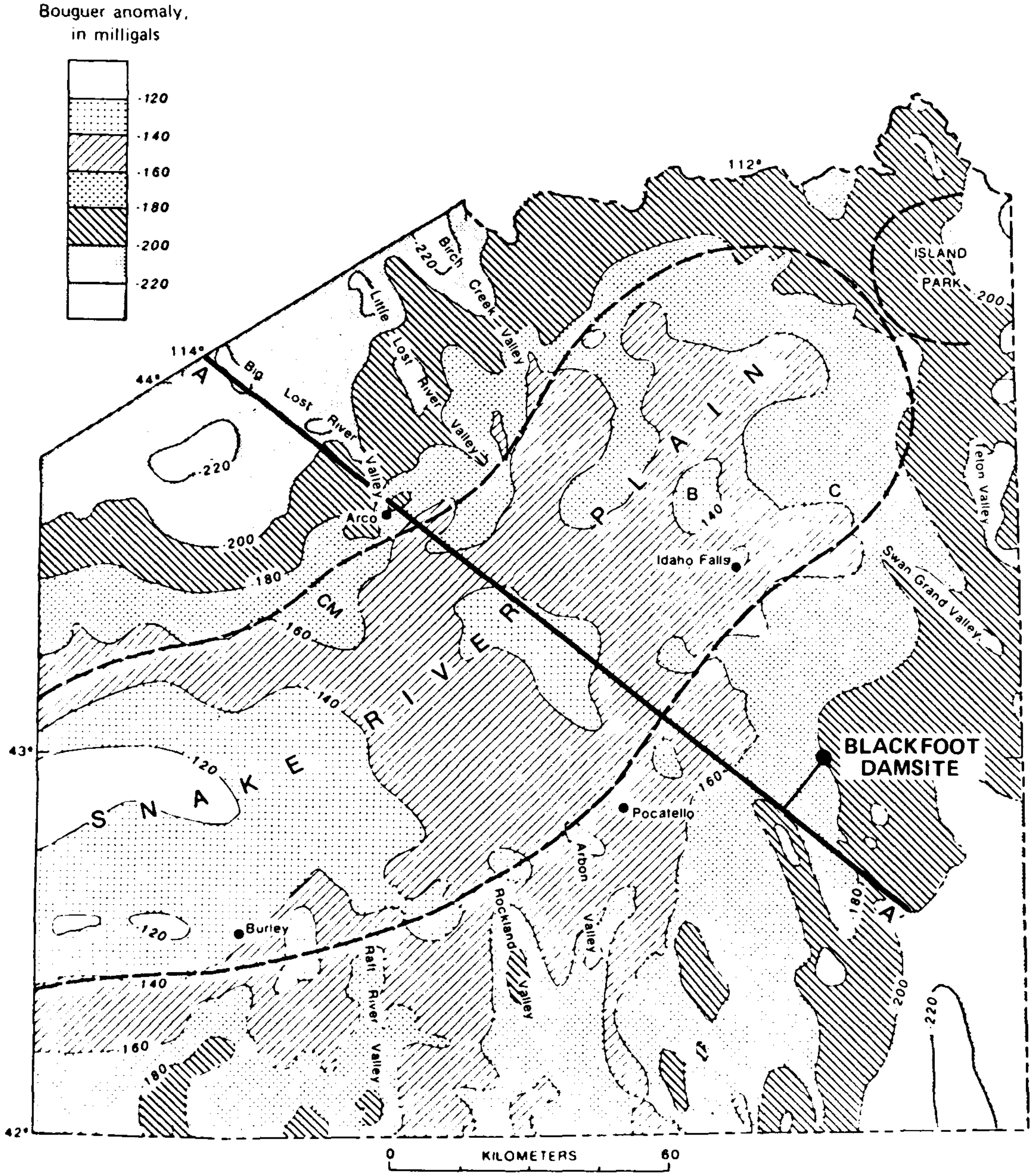


Figure 3. Bouguer gravity anomaly map of southeastern Idaho. From Mabey (1978).

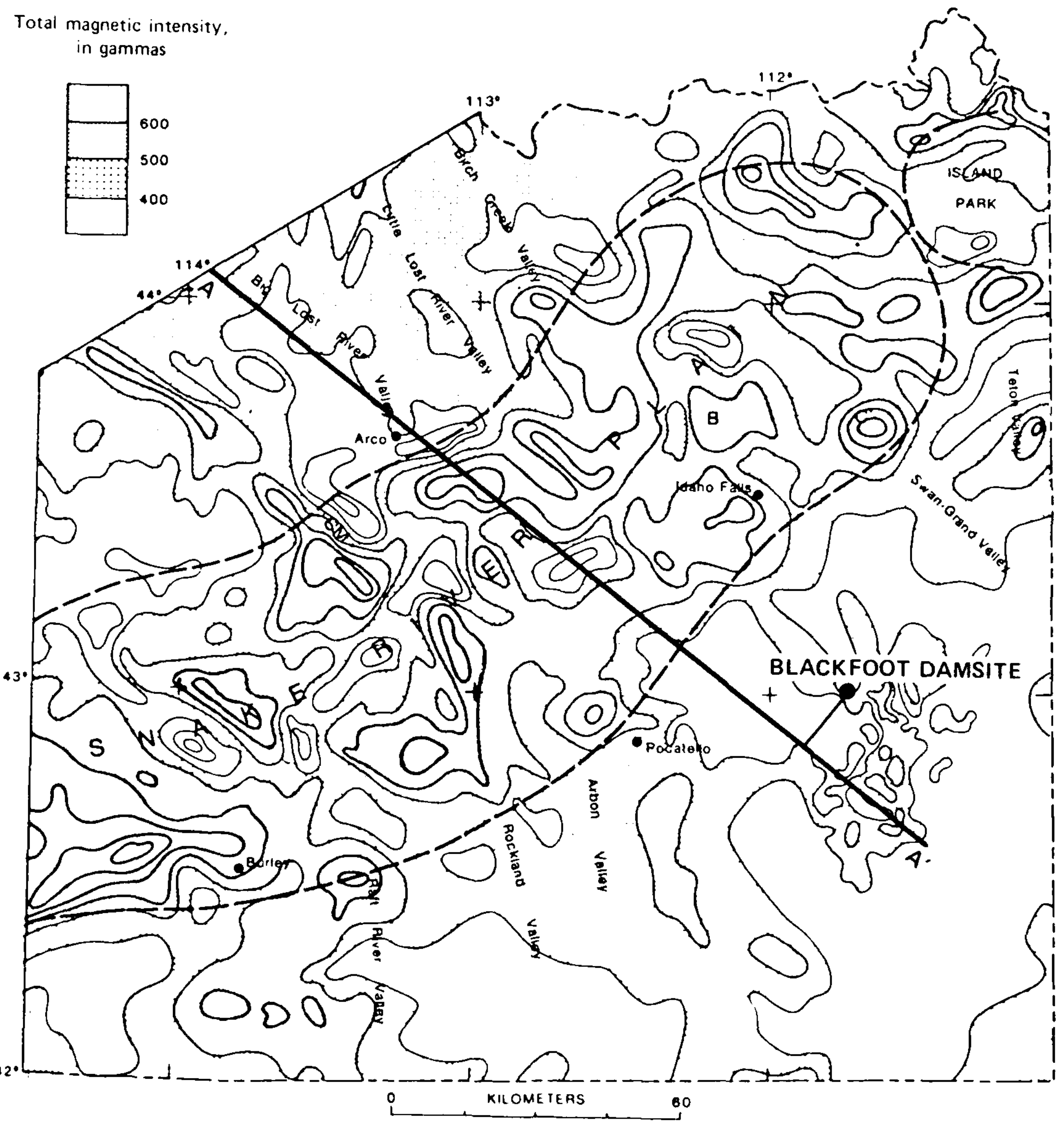


Figure 4. Aeromagnetic intensity map of southeastern Idaho. From Mabey (1978).

10. Figure 5 shows Section A-A' which corresponds to A-A' on Figures 3 and 4. The section shows an interpretation made by Mabey (1978) of the subsurface in the eastern Snake River Plain. Mabey believes that there is a raised block of dense rock several tens of kms below the surface. At and near the surface, to depths as much as several km, the rock density of 2.5 g/cm^3 is somewhat lighter than in adjacent areas. The Blackfoot Damsite is clearly away from the major structural and lithologic controls that have determined the eastern Snake River Plain but the Blackfoot area has been affected to some degree.

11. Volcanic activity from Miocene time to the Holocene has migrated eastward along the Snake River Plain to its present center in the Yellowstone area. The latter may be developing as an extension of the Snake River Plain.

Structural Geology

12. The patterns formed by the major faults in southeastern Idaho and adjacent states are shown in Figure 6. The fault patterns were compiled from state geological maps: Ross and Forrester (1947) for Idaho; Love, Weitz and Hose (1955) for Wyoming; Stokes (1962) for Utah; and Ross, Andrews and Witkind (1958) for Montana. Figure 6 also shows historic earthquakes. Earthquakes will be dealt with in a later section of this report.

13. The faults are mostly north-south but they bend to a northwest-southeast direction where they approach the Snake River Plain. In a general way, they reflect the intraplate boundary and the Intermountain Seismic Belt.

14. The faults terminate when they reach the Snake River Plain. Holocene fault movements have not been found in the Plain. Equally, there is a dearth of historic earthquakes in the Plain.

15. The absence of major faulting and the absence of earthquakes in the eastern Snake River Plain indicates that the earth's crust in this area is in a state of very low stress. Mabey (1978) speculates that a possible cause is that there are exceptionally high thermal gradients.

16. Figure 7 shows a greatly generalized view of the geological structure as it relates to the Blackfoot site. Blackfoot Reservoir is situated in the Bear Lake graben which includes Bear Lake to the south. To the east, the

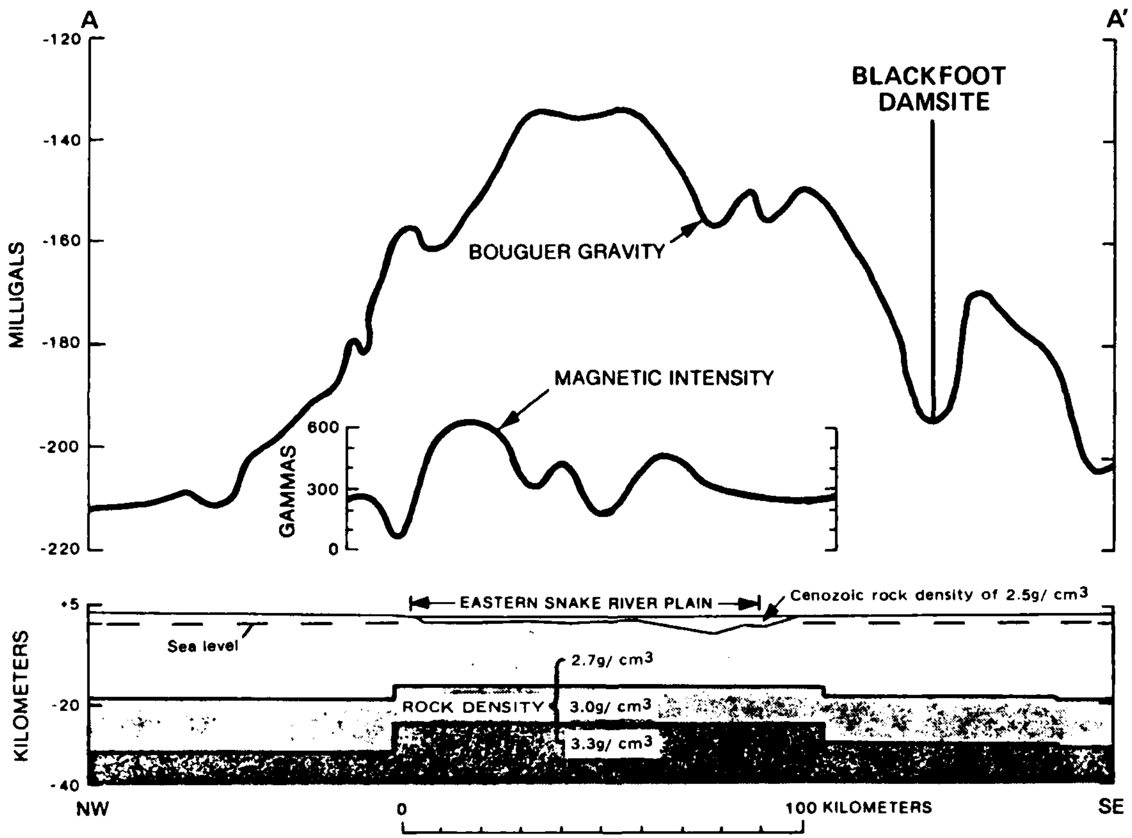


Figure 5. Gravity and magnetic intensity profiles across the Snake River Plain and adjacent areas, with subsurface interpretation. From Mabey (1978).

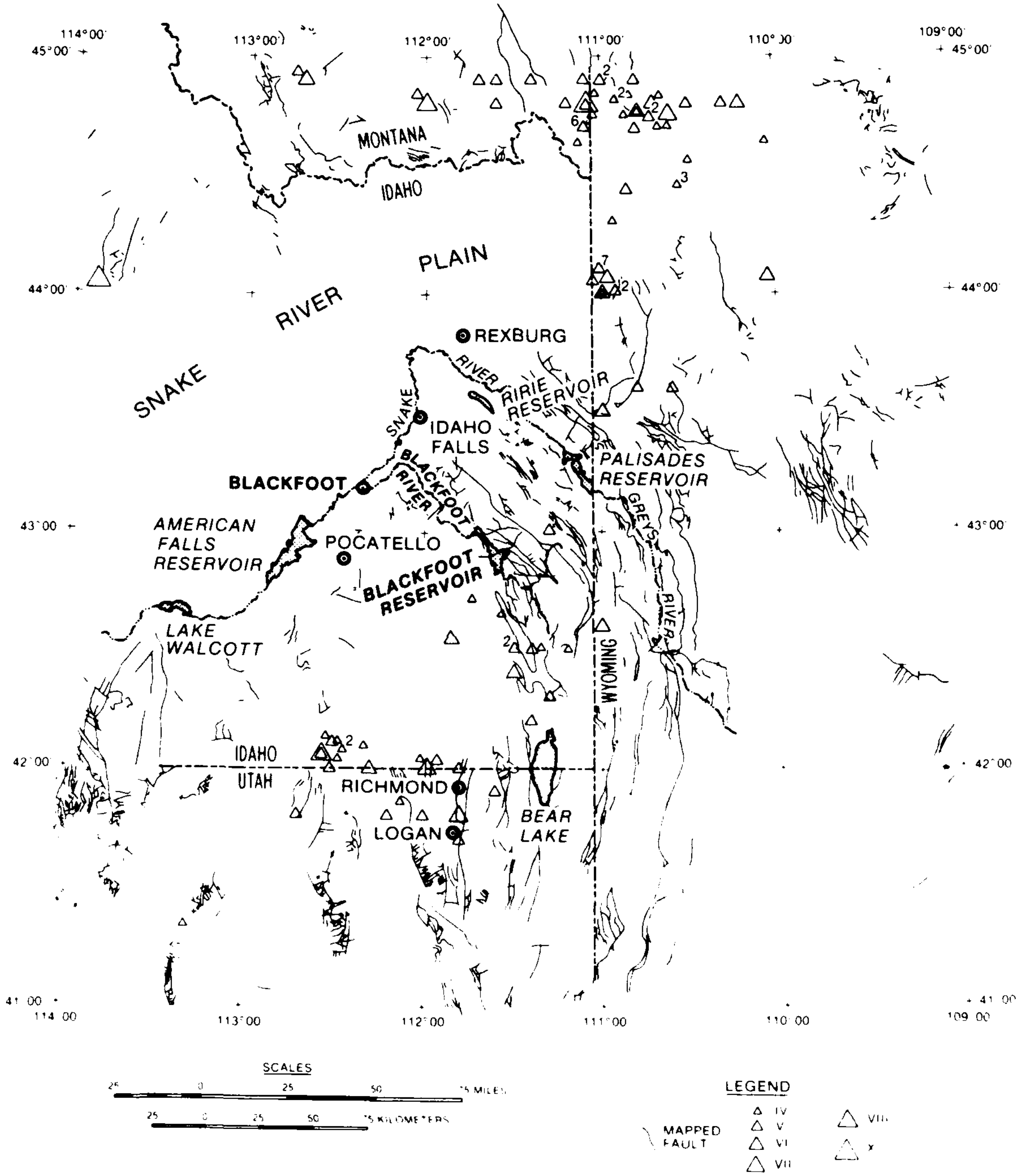


Figure 6. Major faults and earthquakes.

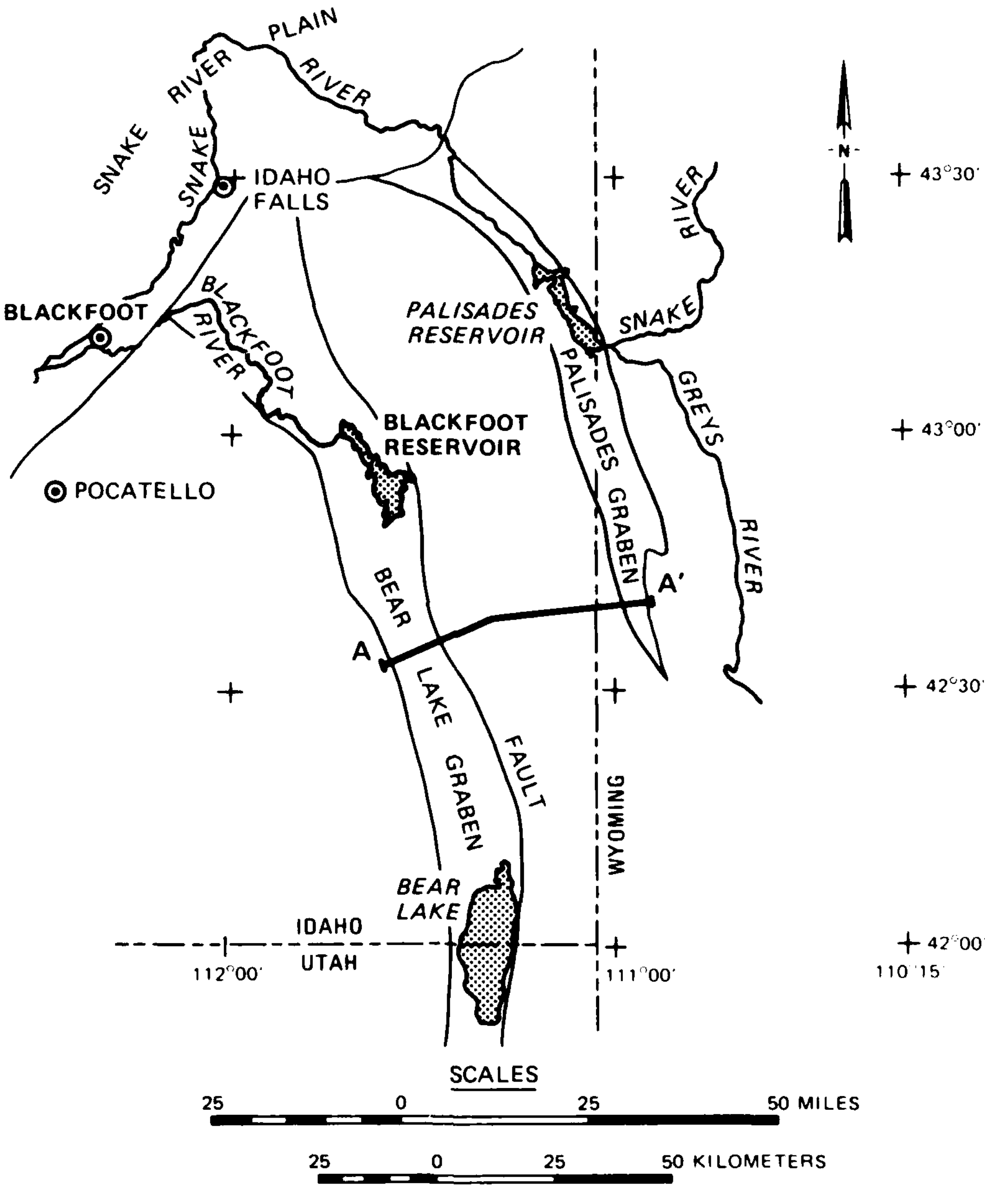


Figure 7. Generalized plan of the Bear Lake and Palisades Grabens. Section A-A' is shown in Figure 8.

Palisades Reservoir is in a similar graben. These structures were taken from the geologic mapping done by Oriel and Platt (1980) but have been greatly simplified. Additionally, Bear Lake Fault as shown on Figure 7 is not a single fault but is a composite of a trend of several faults.

17. Section A-A' across the Bear Lake and Palisades Grabens is shown in Figure 8. Interpretation of the subsurface is by Dixon (1982). The sedimentary series is composed of rocks from Tertiary to Paleozoic age. These overlie Precambrian metamorphic and crystalline igneous rocks at great depth. Seismic profiles show a deep seated, low-angle overthrusting of the sedimentary series. Subsequent tensional forces have caused large wedge-shaped slippage blocks to develop within the sedimentary layers. Quaternary valley fill and volcanic deposits have been introduced in the structurally controlled valleys. The principal valleys are those that are part of the Bear Lake and Palisades Grabens.

18. A characteristic of these grabens is that they are downthrown most strongly along their eastern boundaries, reflecting a rotation of the wedge-shaped displacements in the subsurface.

Active Faults

19. Major active faults in the region surrounding Blackfoot Reservoir are shown in Figure 9. The faults were mapped by Witkind (1975a, 1975b). Details from his descriptions are presented in Table 1.

20. Fault Number 25, west of Bear Lake, extends en echelon for a distance of 55 to 60 miles. Fault Number 24, east of Bear Lake, is also 60 miles or longer. The latter fault extends to the vicinity of Blackfoot Reservoir and bounds the Bear Lake Graben. The faults on the east side of Palisades Reservoir, Numbers 20, 21, 22, and 98, may be interconnected with each other. Combined, they have a length of about 100 miles.

21. Faults 20 and 21, south of Palisades Reservoir, show Holocene movement. The Rock Creek fault, Number 16, which is a bounding fault for the Palisades Graben, moved during historic time about 100 years ago. It has scarps that are 50 to 60 ft high in young alluvial deposits. The Hoback fault, Number 35, cuts surficial loess deposits and has scarps 50 ft high.

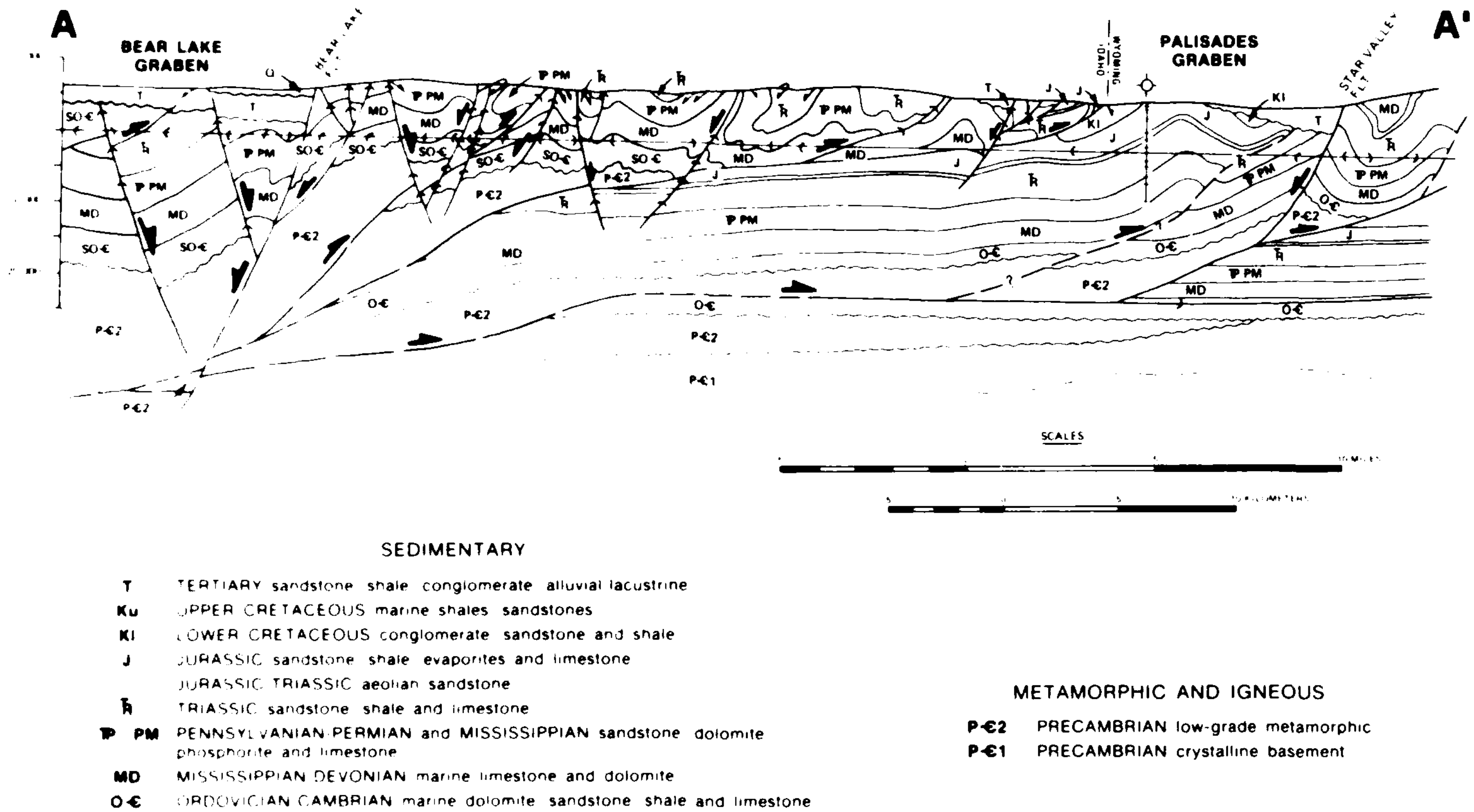


Figure 8. Geological cross section through the Bear Lake and Palisades Grabens. From Dixon (1982). Location of Section A-A' is shown in Figure 7.

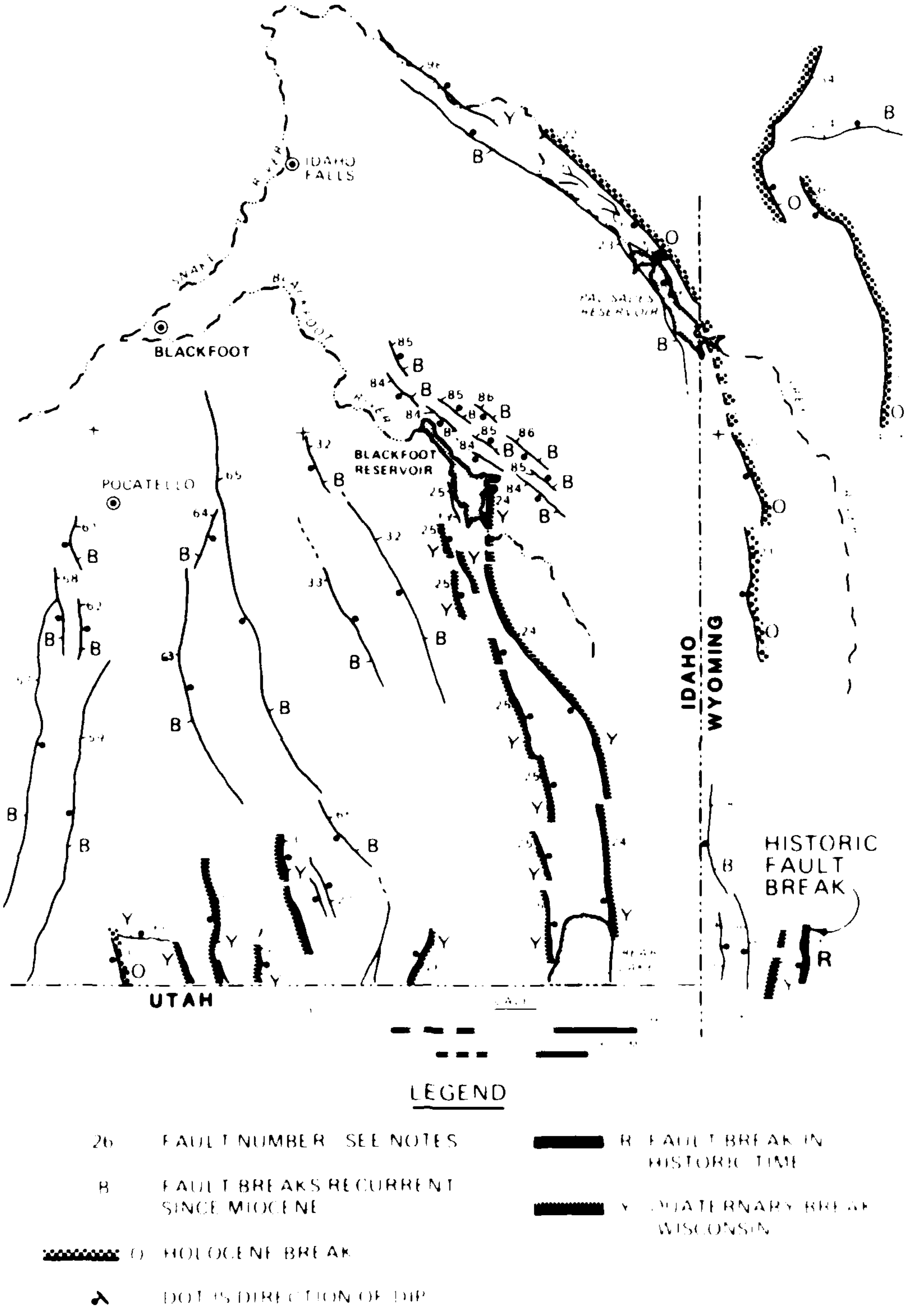


Figure 9. Major active faults in the general area of Blackfoot Reservoir. From Witkind (1975a, 1975b).

22. The dimensions and recency of these fault movements are compelling evidence of susceptibility to great earthquakes.

23. In the environs of Blackfoot Reservoir (Figure 9), the faults have less continuity than elsewhere. Individual fault lengths are 3 to 8 miles. Maximum combined lengths of the segments is about 30 miles.

24. Faults at the Blackfoot Reservoir, mapped by Oriel and Platt (1980), are shown in Figure 2. The faults are numerous, relatively short, and discontinuous. Lengths are 8 miles or less. All of these faults may be presumed to be active.

25. No faults were evident at the sites of either Blackfoot Dam or China Hat Dam.

Volcanism

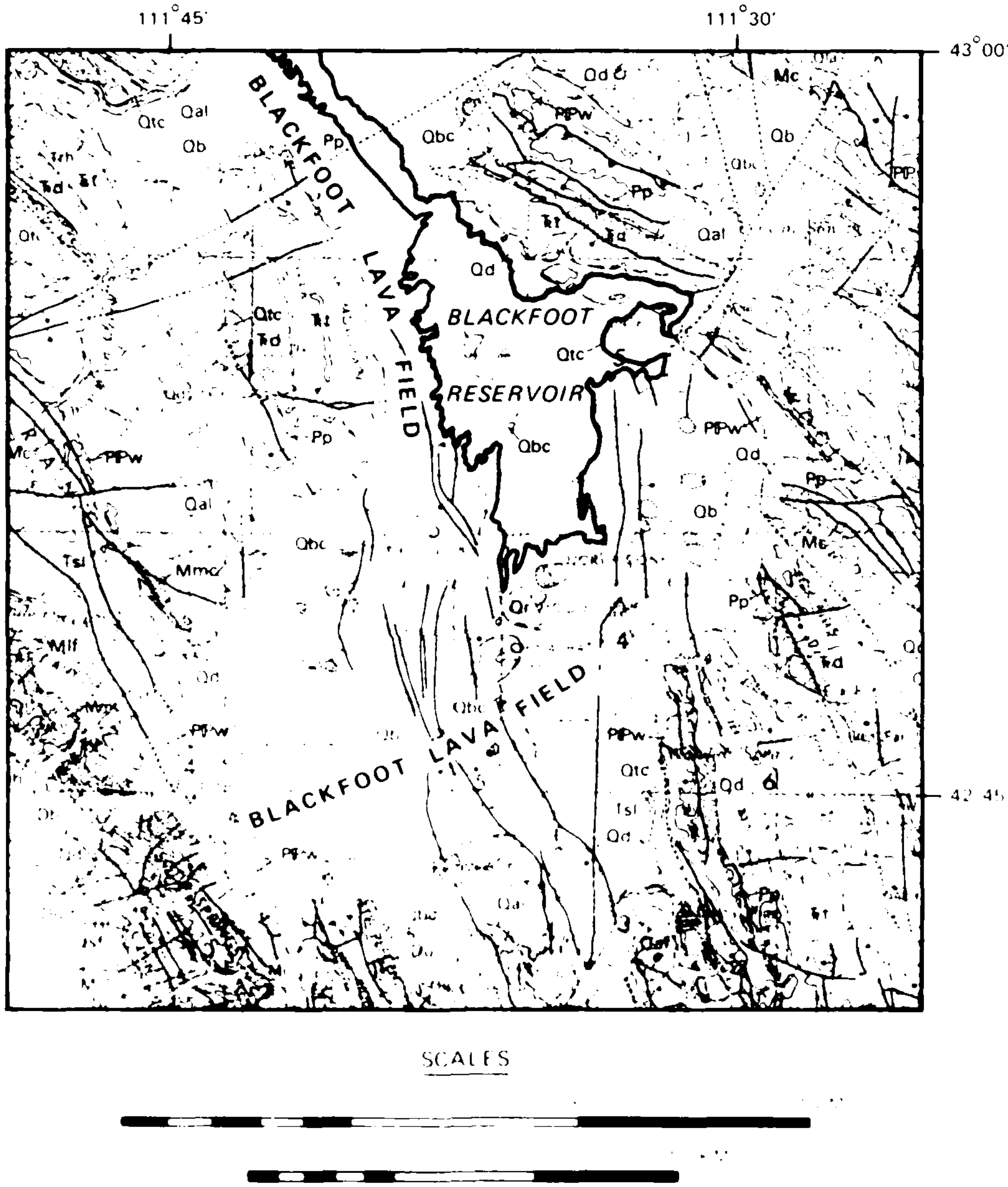
26. Blackfoot Reservoir is entirely in a valley that was filled with lava. Figure 10 shows the reservoir and the extent of the Blackfoot Lava Field. The lava is in the form of multiple irregular sheets which were identified by Oriel and Platt (1980) as Pleistocene to Pliocene in age.

27. The lava is in the form of basalts that are black scoria and black glassy flows. Some cone material is loose scoriaceous and red-weathering cinders. Locally, there are small intrusions of rhyolites, which are tan-weathering and fine-grained to microcrystalline. Older basalts are dark gray and vesicular, sometimes microcrystalline, sometimes porphyritic.

28. The appearance of lava exposed in the left abutment of Blackfoot Dam is seen in Figure 11.

29. The composite section of basalts varies greatly in thickness. Mapping done by Mabey and Oriel (1970) interprets gravity lows, shown in Figure 12, in the southern area of Blackfoot, further south near Soda Springs and in a valley about 15 miles to the west. These are deeply filled troughs in valleys that are fault controlled.

30. The troughs may be mostly filled with sediments. Mabey and Oriel (1970) cite a well near Soda Springs, [illegible] ft deep, which penetrated [illegible] ft of Salt Lake formation, and may have bottomed in Triassic strata. Thus, the gravity lows are evidence for fault activity but not necessarily for very great thicknesses of volcanic deposits.



[illegible] map of Oriel and Platt (1980), [illegible] shows the situation of the Blackfoot Reservoir in [illegible] lava fields.

Figure 11. Lava of the Blackfoot Lava Field seen in the left abutment of Blackfoot Dam.

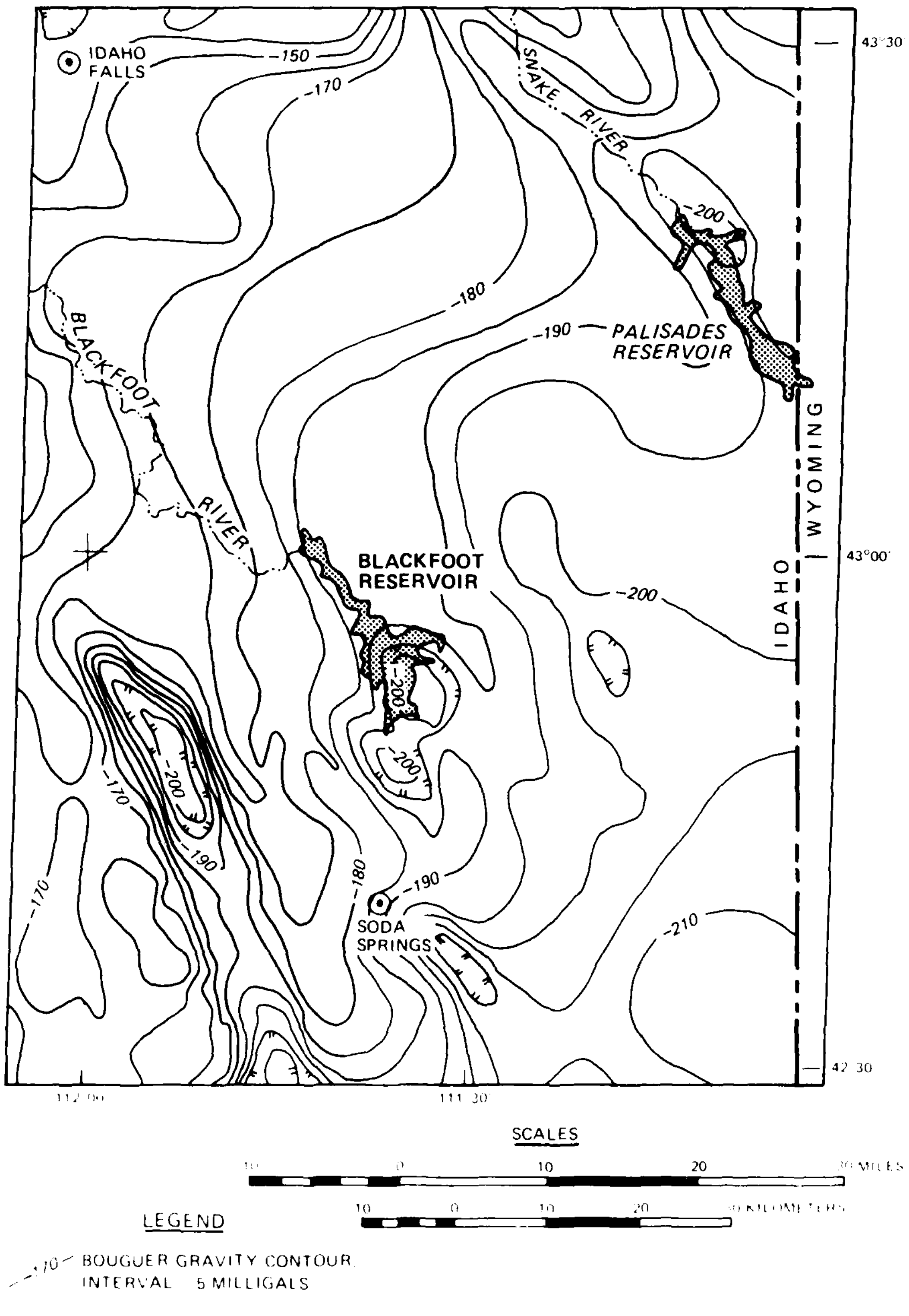


Figure 12. Bouguer gravity contours in the region of Blackfoot Reservoir. From Mabey and Oriel (1970).

31. Mabey and Oriel (1970) speculate from gravity values combined with magnetic data that lava in the northwest portion of the Blackfoot Lava Field (Figure 10) is about 400 ft thick.

32. The Blackfoot Lava Field contains small hills that are composed of rhyolite volcanic rocks. These may have been focal points of magma intrusion. Mabey and Oriel (1970) suggest that the compound circular gravity anomaly at the south end of the Reservoir may be a caldera resulting from this extrusion of molten rock.

33. Results from age dating of volcanic deposits, done by Armstrong, Leeman and Malde (1975), are shown in Figure 13. What is most notable is that samples taken along the edge of Blackfoot Reservoir provided ages of 100,000, 80,000, and 40,000 years.

34. In the Blackfoot area, volcanism has been so very recent that it can be considered to be continuing.

Hot Springs and Travertine Deposits

35. Hot springs are additional evidence of present-day tectonism in the Blackfoot area.

36. Sites of hot springs, from work done by Mitchell, Johnson and Anderson (1980), are shown in Figure 14. Data for these sites are presented in Table 2. Five sites are situated in the vicinity of the Blackfoot Reservoir.

37. Figure 15 shows a hot spring at location Number 5 (see Figure 14) at the north end of Blackfoot Reservoir. A rim of travertine rises above the spring, having been precipitated from an older source.

38. The springs emanate from almost any of the rock types in this region as well as from rocks of any age. Temperatures in the springs are moderate. Discharges vary enormously.

39. Travertine can be deposited rapidly. Flow from a newly drilled well built a circular mound over 60 ft in diameter and 4-1/2 ft high in six years (see Mitchell, 1976) develop crusts several feet thick in a year. Older deposits that were 40 ft thick were reported by Mitchell and his colleagues (1980).

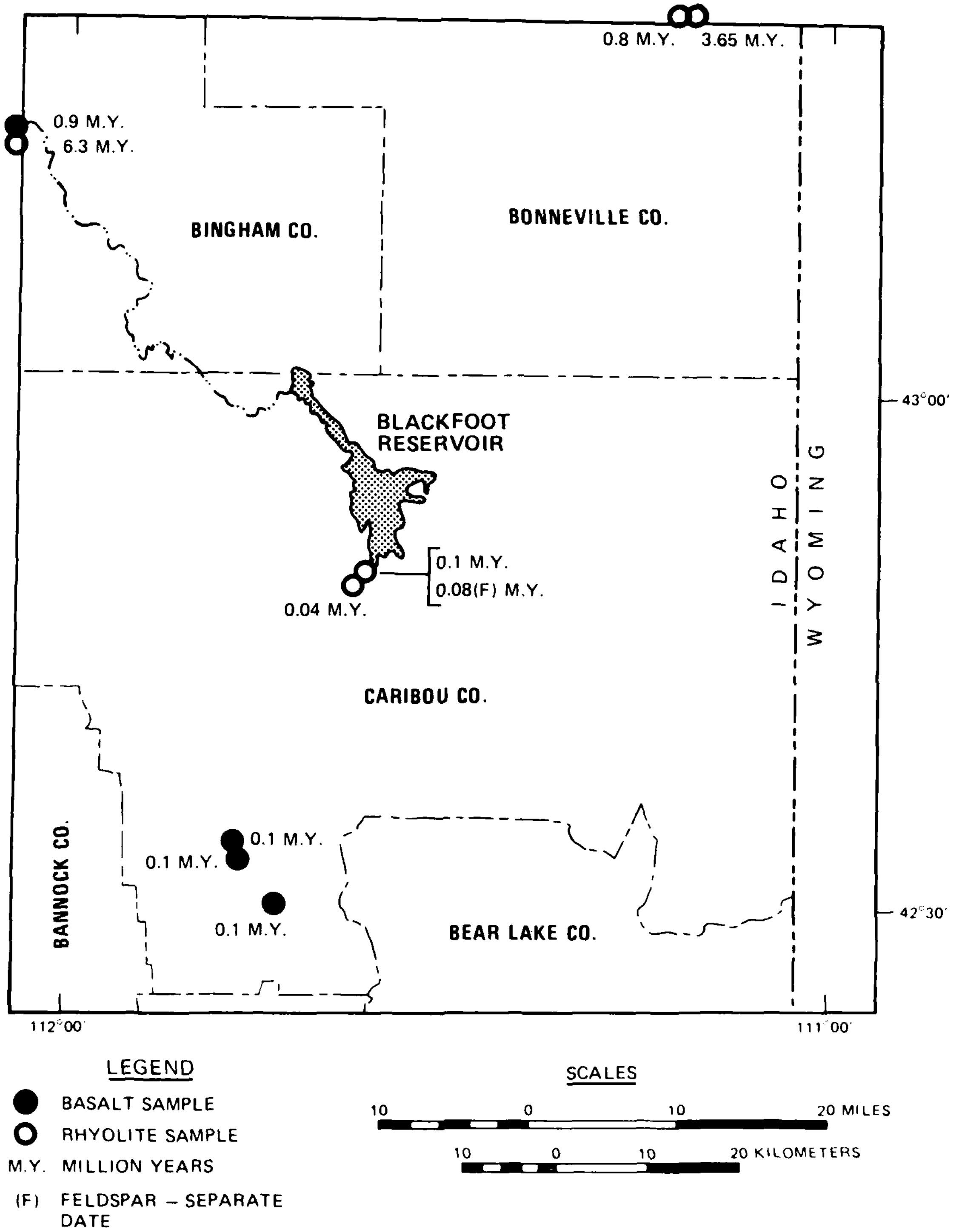


Figure 13. Results from age dating of volcanic deposits. From Armstrong, Leeman and Malde (1975).

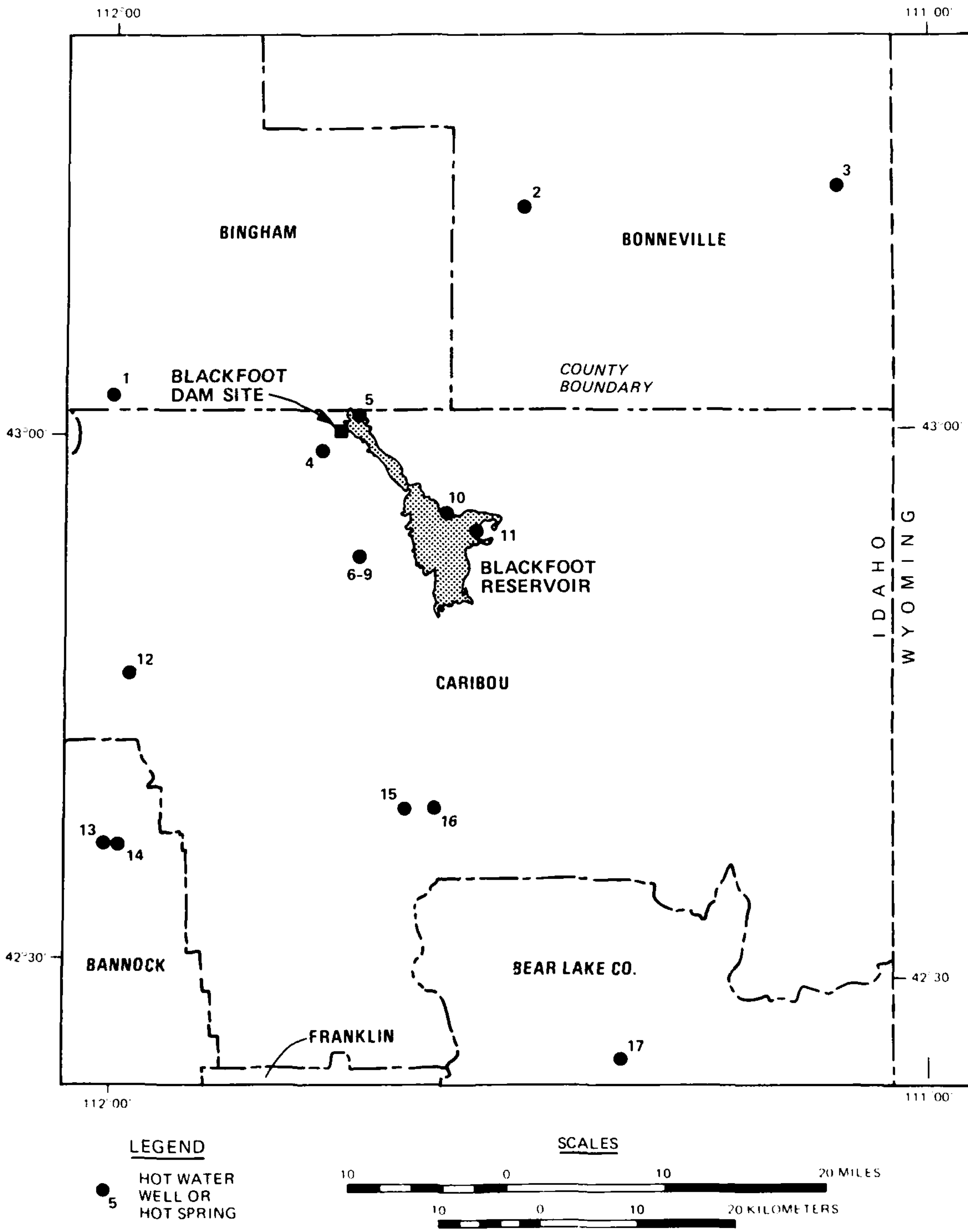


Figure 14. Locations of hot springs in the Blackfoot area. For corresponding data, see Table 2. From Mitchell, Johnson and Anderson (1980).

Figure 15. Hot spring and travertine deposit at the north end of Blackfoot Reservoir.

40. Figure 16 shows how extensively travertine deposits have developed at Blackfoot Reservoir and along the Bear Lake Graben. The travertine provides additional confirmation of tectonic activity in the graben.

Lava Flows and Loess

41. Lava flows were correlated in borings at Ririe Dam, 62 km north of Blackfoot Dam. Figure 9 shows the location of Ririe Dam. Patrick and Whitten (1981) found the basalt layers at Ririe to be 20 to 80 ft in maximum thickness. These are older basalts than those at Blackfoot, yet one should expect many similar layers at Blackfoot.

42. The region of the Snake River Plain and its southern margins are extensively covered with both eolian sands and layers of loess, a windblown silt. Scott (1982) recognized six loess sheets plus five sand horizons.

43. There is a possibility that basalt sheets at the Blackfoot Dam may contain buried loess layers or buried eolian sands.

44. Saturated loess is susceptible to liquefaction from earthquake shaking. This susceptibility was demonstrated during the Bucharest earthquake of 4 March 1977 which caused liquefaction in loess in Bulgaria, 200 to 300 km from the source (see Minkov and Evstatiev, 1979). Leakage from the reservoir through the fractured basalts would have saturated any buried soil layers.

45. It would be desirable to check out the possibility of liquefaction-susceptible sand or silt in the foundation at Blackfoot Damsite by drilling to at least 50 ft in the basalts.

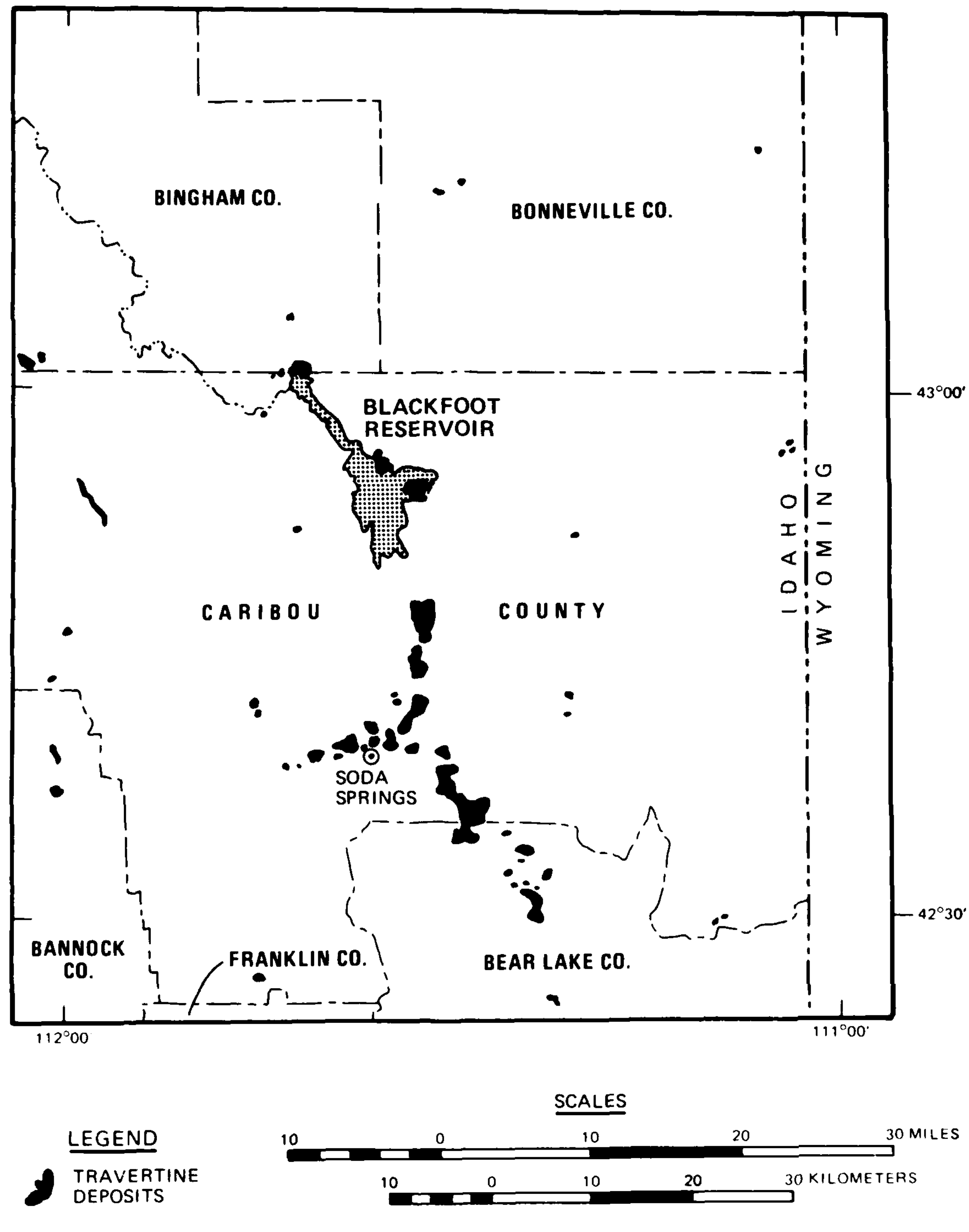


Figure 16. Location of major travertine deposits in the Blackfoot area. From Mitchell, Johnson and Anderson (1980).

PART III: SEISMIC HISTORY

Distribution of Earthquakes

46. The distribution of historic, felt earthquakes in the general region of Blackfoot Reservoir (109.5 to 114.0 degrees longitude; 41.0 to 45.0 degrees latitude) is seen in Figure 6. These earthquakes are tabulated in Appendix A from data edited by Coffman, von Hake and Stover (1982).

47. The earthquake history in this region is the shortest in the United States, dating from 1880 in the area covered by Appendix A and from 1854 in the larger area of the Intermountain Seismic Belt shown in Figure 1.

48. Earthquakes of MM Intensity VII or greater in Idaho and parts of adjacent states are shown in Figure 17. They are randomly distributed throughout the mapped area and they do not identify any dominating trends.

Relation of Seismicity to Geology

49. Fault plane solutions for earthquakes, as developed by Smith and Sbar (1974), are shown in Figure 18. South of the Snake River Plain, there is a predominance of movements on normal faults resulting from tensional forces acting in an east-west direction, but with some strike-slip components. The Snake River Plain and Idaho Batholith are inactive. Peripheral areas to the northeast have mostly normal and strike-slip faults but with north-south directions of spreading.

50. Smith and Sbar (1974) postulate that the pulling apart of the crust in this region results from convection currents caused by a thermal plume emanating from deep in the subsurface.

51. The mapped faults in Figure 6 indicate a potential for widespread severe earthquakes. However, until recently, the historic earthquakes in southeastern Idaho have not been related to specific causative faults. To the north of the Snake River Plain, at Hebgen Lake, Montana, the earthquake of 17 August 1959 (see Figure 17) produced surface fault ruptures. And very recently, the SE Idaho earthquake of 28 October 1983 produced surface fault displacements. The absence of similar associations elsewhere may be attributed to the very short historic record and sparseness of settlement.

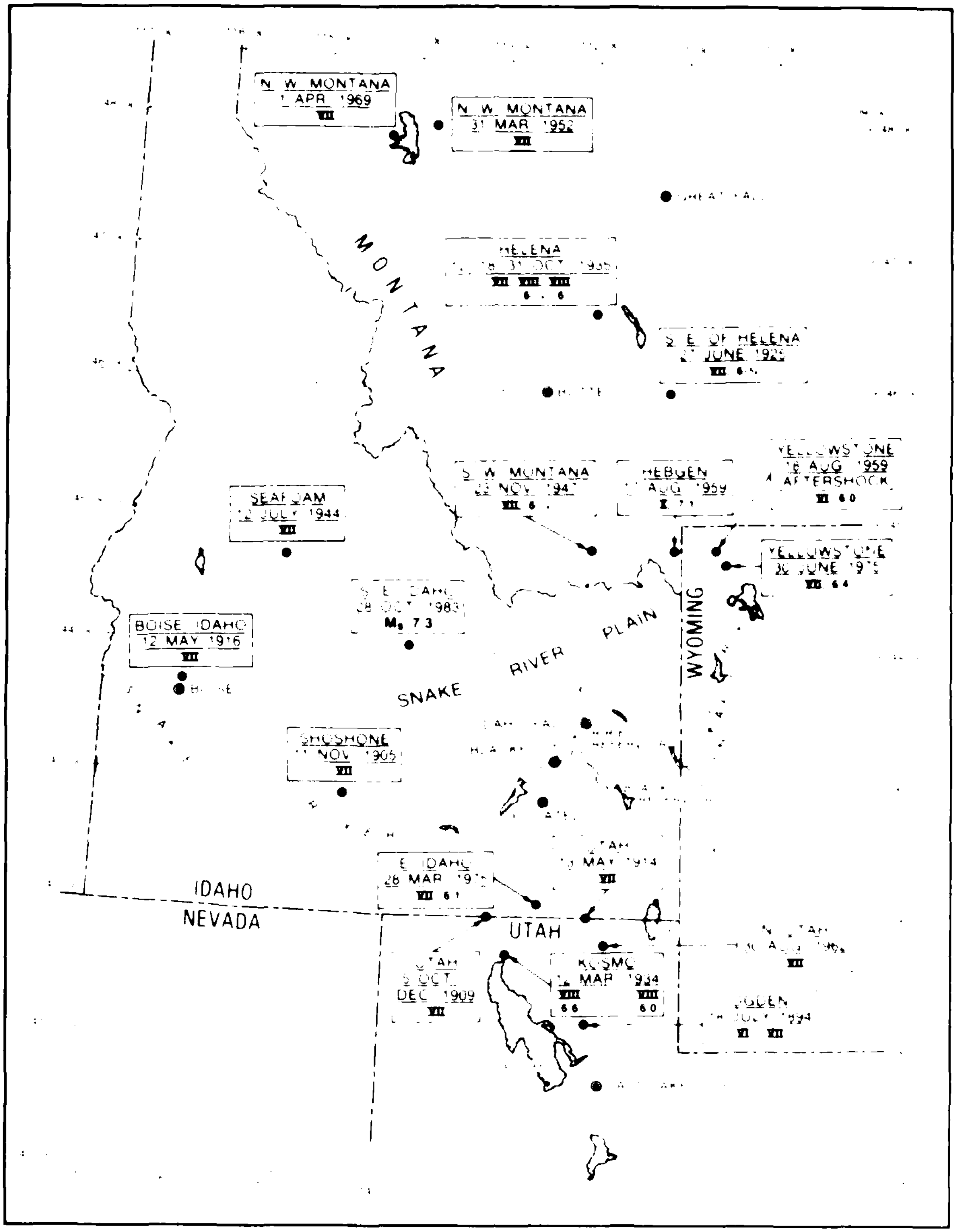
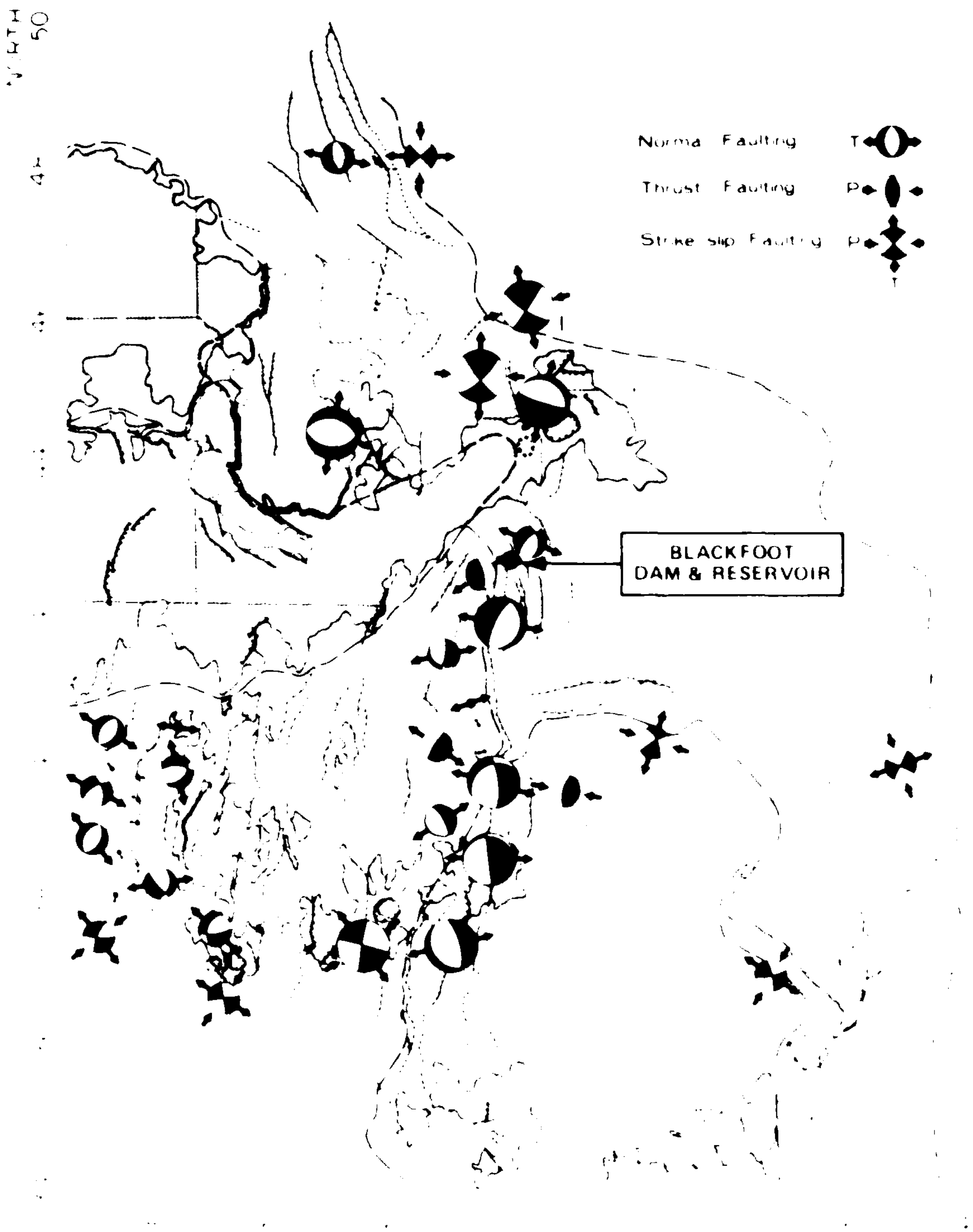


Figure 17. Historic felt earthquakes greater than MM Intensity VII in Idaho and adjacent areas.



Normal Faulting T
Thrust Faulting P
Strike slip Faulting P
BLACKFOOT
DAM & RESERVOIR

51. The potentials of faults for generating earthquakes in the Blackfoot area have to be based on geologic and other evidence and not on that from the historic seismicity.

Microearthquakes

52. [illegible] earthquakes, those earthquakes that are too small [illegible] can define the [illegible] of fault [illegible] movement. [illegible] movement [illegible] However, [illegible] these [illegible] can furnish [illegible].

53. [illegible] microearthquakes in the region of [illegible] Bureau of [illegible] Reclamation in [illegible] the [illegible] the northeast. [illegible] results [illegible] the University of Utah network [illegible].

54. [illegible] results [illegible] Bureau of Reclamation* [illegible]

55. [illegible]

[illegible] earthquakes.

56. [illegible] earthquakes in the Blackfoot [illegible] potentials for [illegible] earthquakes,

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* [illegible] obtained from Richard Martin and colleagues, Bureau of Reclamation, Denver; obtained on [illegible] July 1983.

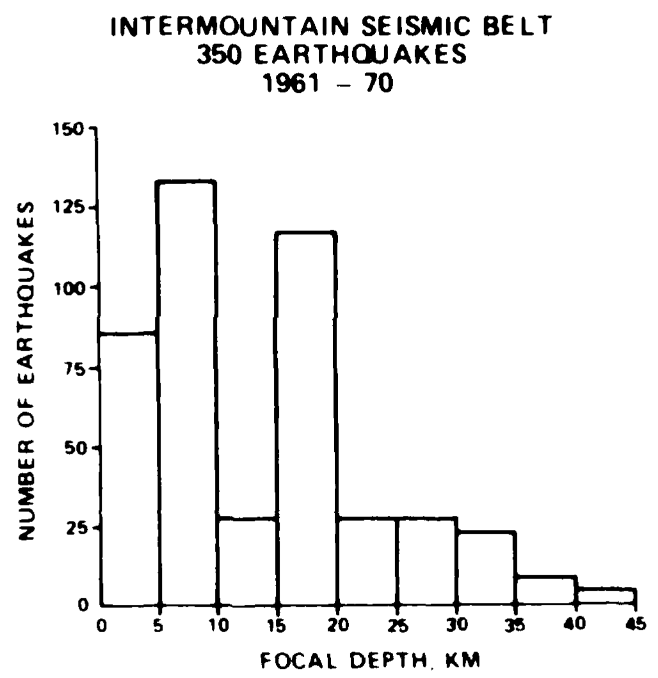


Figure 19. Histogram of focal depths of felt earthquakes, 1961-1970, in the Intermountain Seismic Belt. From Smith and Sbar (1974).

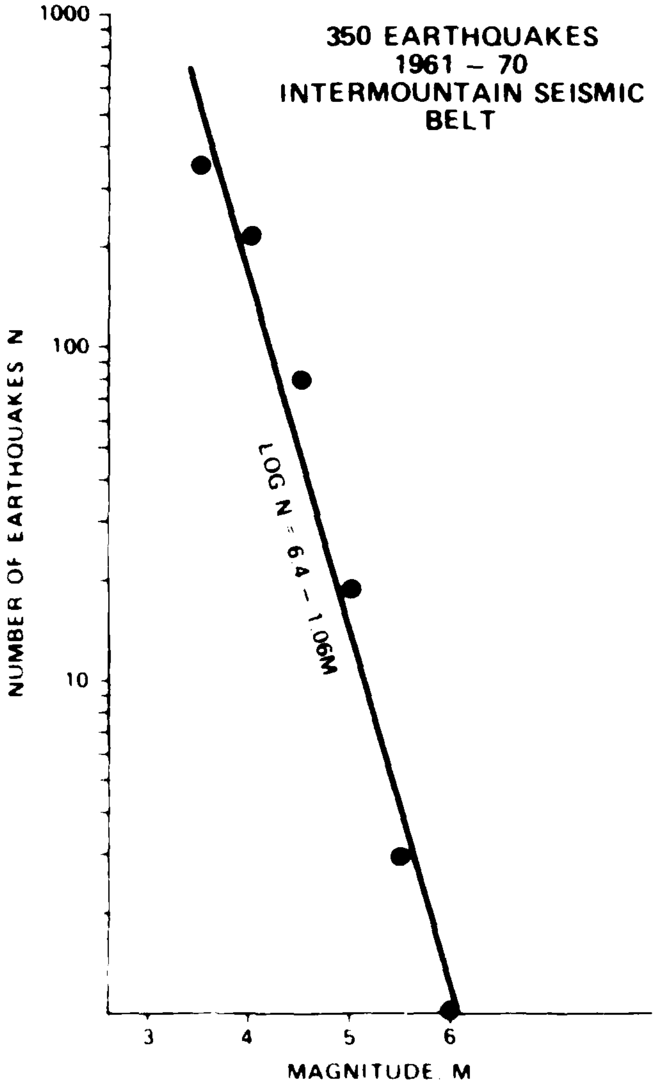
[illegible] necessarily [illegible] earthquakes [illegible] along the [illegible] known [illegible] faults or elsewhere, [illegible] adjacent [illegible] the stations, [illegible] faults which have not been identified.

5. A recent study of microearthquakes was made in an area [illegible], Alaska and Canada [illegible] microearthquakes between [illegible] September and [illegible] November [illegible] October [illegible] microearthquakes [illegible] October [illegible]. These [illegible] the stations. These [illegible] related [illegible] fault. [illegible]

6. Microearthquake [illegible] reported [illegible] stations [illegible]

[illegible]

[illegible]



[illegible] occurrence of earthquakes in the Intermountain Seismic Belt. From Smith and Sbar (1974).

62. The approximately 100-year record in Appendix A shows three magnitude 6 events (1947, two in 1959) and two magnitude 7 earthquakes (1959 and 1983). The historic record is no doubt incomplete, except for the very largest events, but the recurrence patterns within local areas is apt to vary significantly. For the Blackfoot area, probabilities of recurrence at the damsite cannot be estimated reliably because of the extremely short and incomplete historic record.

PART IV: MAJOR EARTHQUAKES FELT AT BLACKFOOT DAMSITE

63. A list of historic earthquakes that can be interpreted as felt at Blackfoot Damsite is contained in Table 3. The intensities at the damsite were taken from isoseismal maps, where available, or were estimated using intensity attenuation curves by Chandra (1979).

64. The severest historic intensity felt at the damsite was MM VI. Shaking at this level was felt once, in 1975, and once in 1983. All other experiences of earthquake shaking were less.

65. Though there are gaps in the historic record, all severe earthquakes should have been noted throughout the past century. It may be assumed that the severest earthquake shaking at the Blackfoot Damsite during the past 100 years was Modified Mercalli Intensity VI.

PART V: EARTHQUAKE MOTIONS AT BLACKFOOT DAMSITE

Recommended Peak Motions

66. The major active faults in the area under investigation are shown in Figure 9. It is an area in which tectonic activity is so great that all faults, whether they have been mapped as active or not, must be regarded as being active and capable of generating earthquakes.

67. In a general sense, the size of an earthquake is in proportion to the size of fault rupture: whereby the greater the fault breakage, the greater the earthquake. The problem with this relationship is that there is an enormous dispersion in the data. Recent charts by Bonilla (1983), see Figures 21 and 22, show the relations between fault displacement, length of surface rupture along faults and earthquake magnitude. The dispersion of the data is one to two orders of magnitude and there seems to be no significant relation as to normal, reverse or strike-slip faulting. The best that one can do is to treat these relationships in a reasonably encompassing way.

68. Reference to Figure 9 shows that the faults closest to Blackfoot Reservoir are relatively short and discontinuous with lengths of 5 to 10 km. On the Bonilla charts, these qualify for an $M_s = 6.0$. Allowing for uncertainties, $M_s = 6.5$ is appropriate for a Near Field floating earthquake at the damsite. The macroseismic observations and the geological observations are reasonably in accord with this value since they do not call for an extreme event. There will be no permanent displacement at the dam, since there are no observed faults at the dam. Somewhat farther from Blackfoot Reservoir, are longer faults that border Palisades Reservoir to the northeast, fault 24 to the south, and fault 32 to the southwest. $M_s = 7.5$ represents a saturation of peak motions such as acceleration and velocity and may be taken as the worst to be expected from these sources, yet the maximum magnitude is not the greatest, which might be $M_s = 8.5$. Thus $M_s = 7.5$ is in accord with a situation where thermal effects at depth is a moderating influence. Near Field motions for $M_s = 7.5$ at a distance of 30 km would account for these sources. Finally, there are large potential earthquakes from greater distances. These can be taken as $M_s = 7.5$, for Far Field motions for a distance of 80 km.

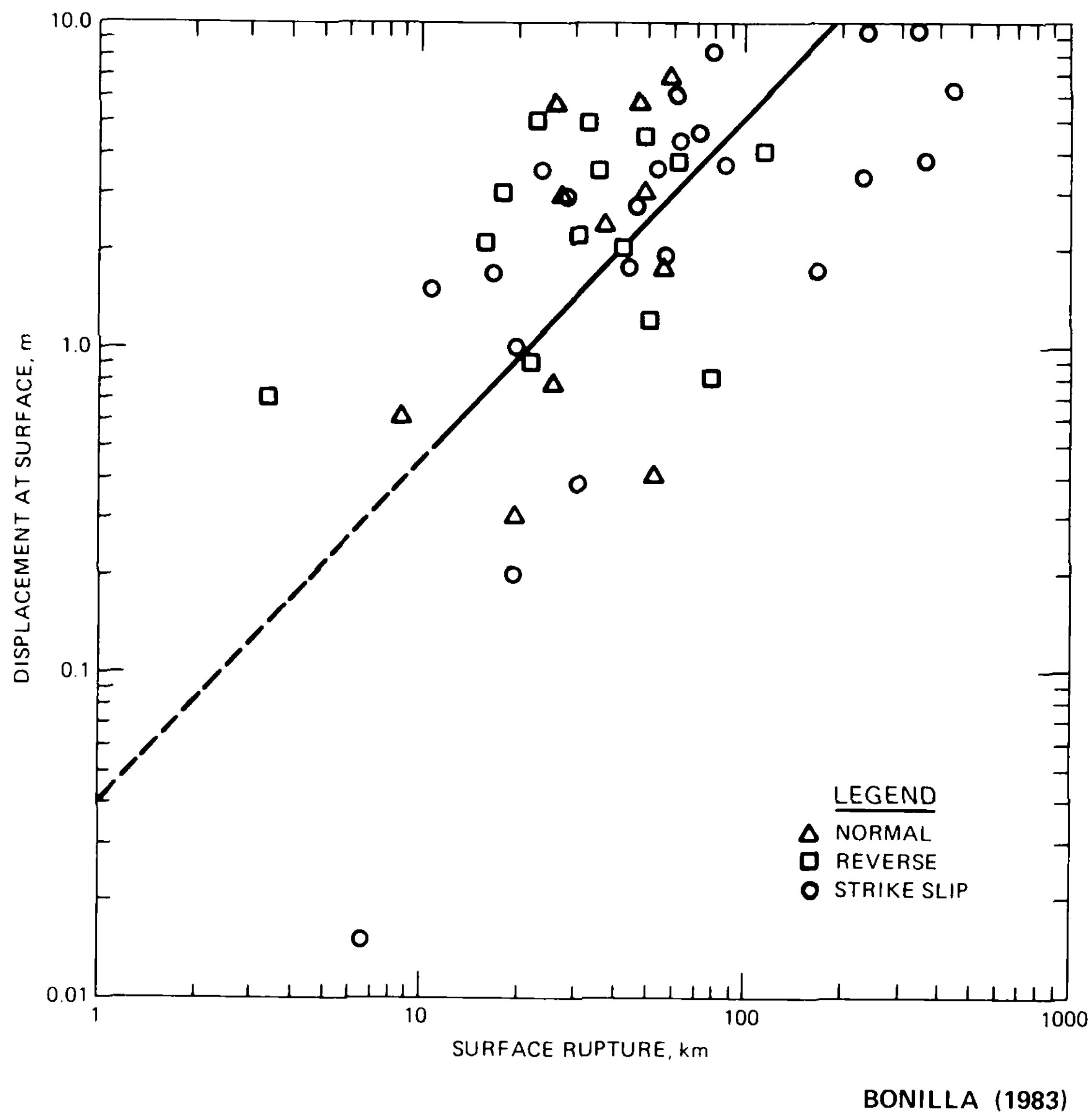


Figure 21. Relation between displacement at surface and length of surface fault rupture. From Bonilla (1983).

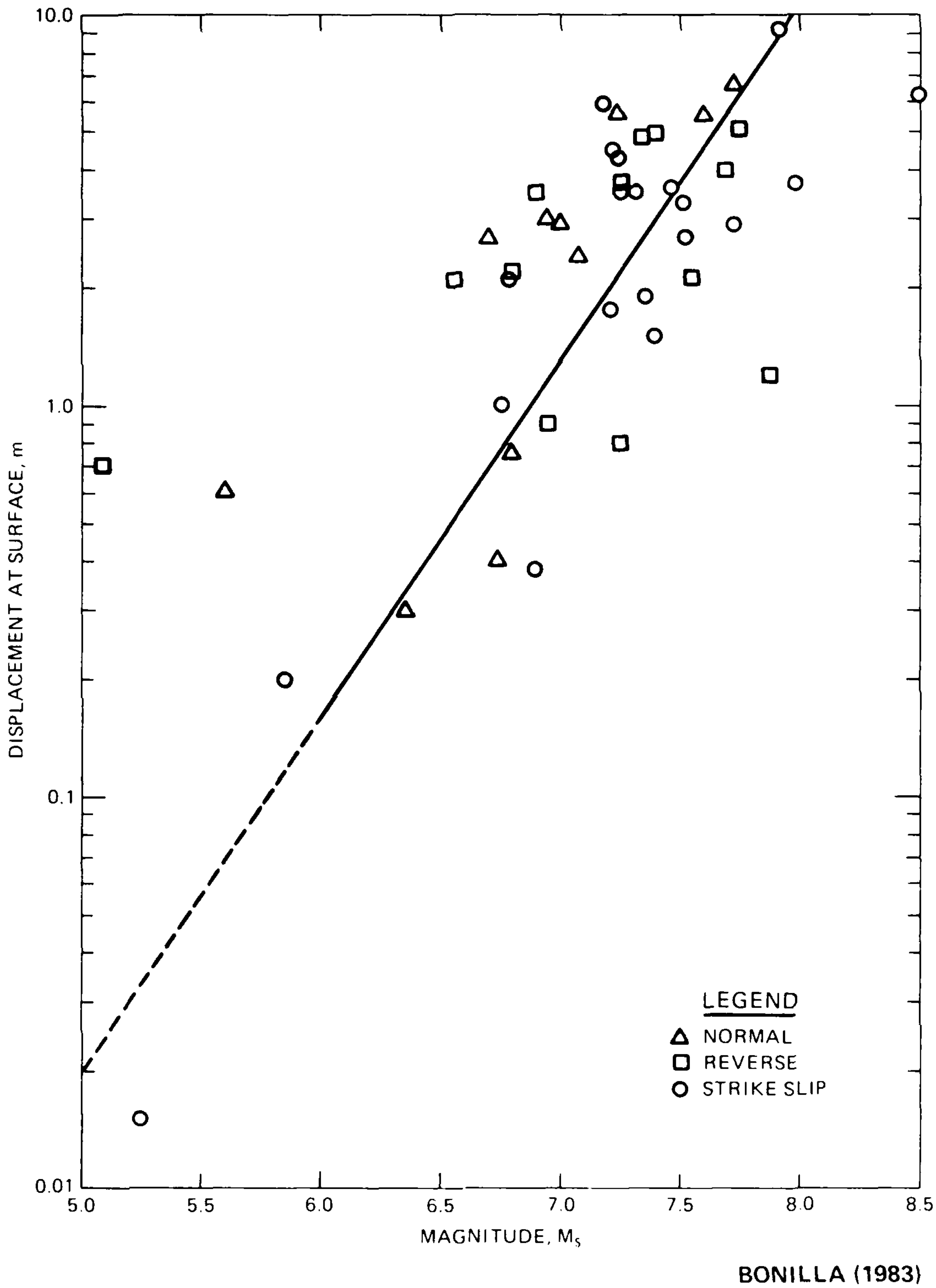


Figure 22. Relation between displacement at surface and earthquake magnitude, M_S. From Bonilla (1983).

69. The relation between earthquake magnitude (M_s), epicentral intensity, and limits of the Near Field are given in the following set of relations from Krinitzsky and Chang (1977):

M_s	MM Maximum Intensity, I_o	Radius of Near Field, km
5.0	VI	5
5.5	VII	15
6.0	VIII	25
6.5	IX	35
7.0	X	40
7.5	XI	45

70. Attenuation of MM intensity with distance was done by using the curves by Chandra (1979), presented in Figure 23, and using the attenuations that Chandra shows for the Cordilleran Province as interpreted by Howell and Schultz.

71. Peak motions appropriate for MM Intensity at the Blackfoot damsite are from Krinitzsky and Chang (in press). These are presented as charts for horizontal acceleration, velocity and duration for Near Field, Hard Site (Figure 24) and Far Field, major earthquakes, Hard Site (Figure 25). The level of motions are taken at mean plus one standard deviation or 84 percentile, which puts one in a conservative position. The resulting horizontal earthquake motions are as follows:

a. Local Source, Near Field at the Dam:

M_s:	6.5
MMI_s:	IX
Distance, km:	0
Site:	Rock
Accel, g:	0.68
Vel, cm/sec:	60
Dur, sec:	10

b. Near Source, Near Field at the Dam:

M_s:	7.5
MMI_s:	I_o = X, reduced to I_s = IX
Distance, km:	30
Site:	Rock

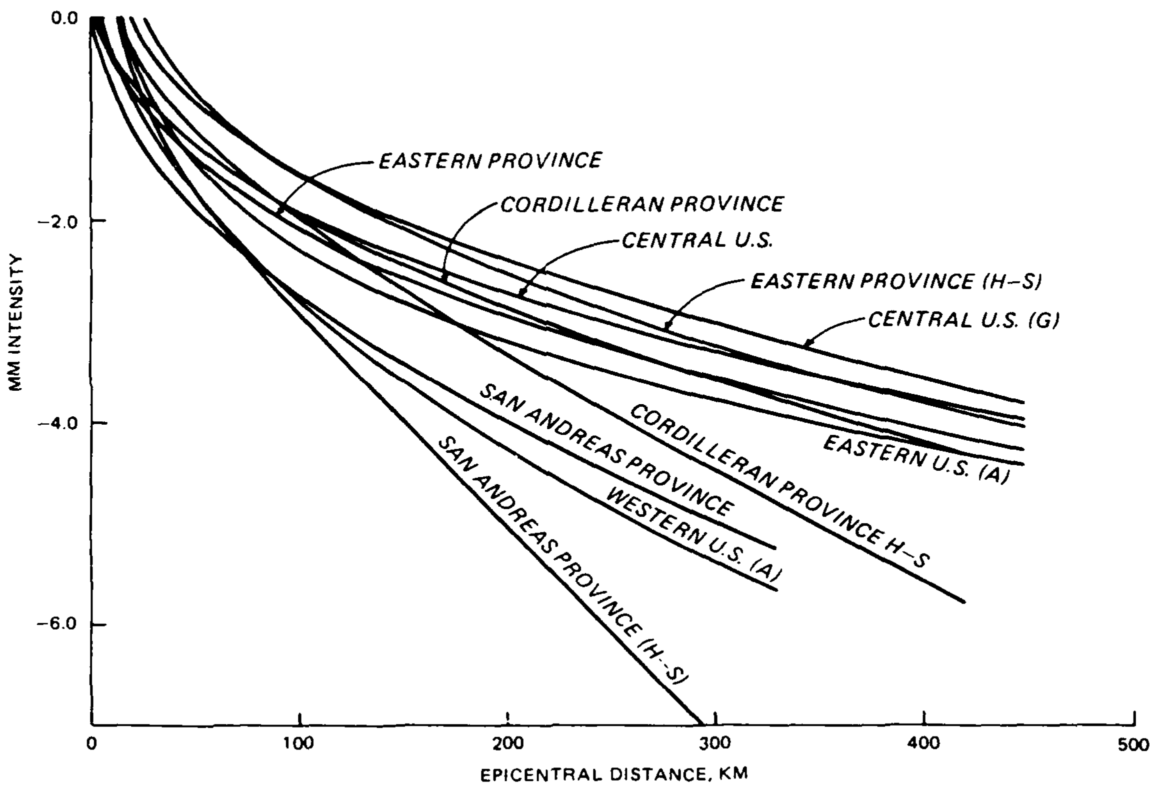


Figure 23. Attenuation of MM intensities with distance. On curves, A = Anderson, G = Gupta, H-S = Howell-Schultz. From Chandra (1979).

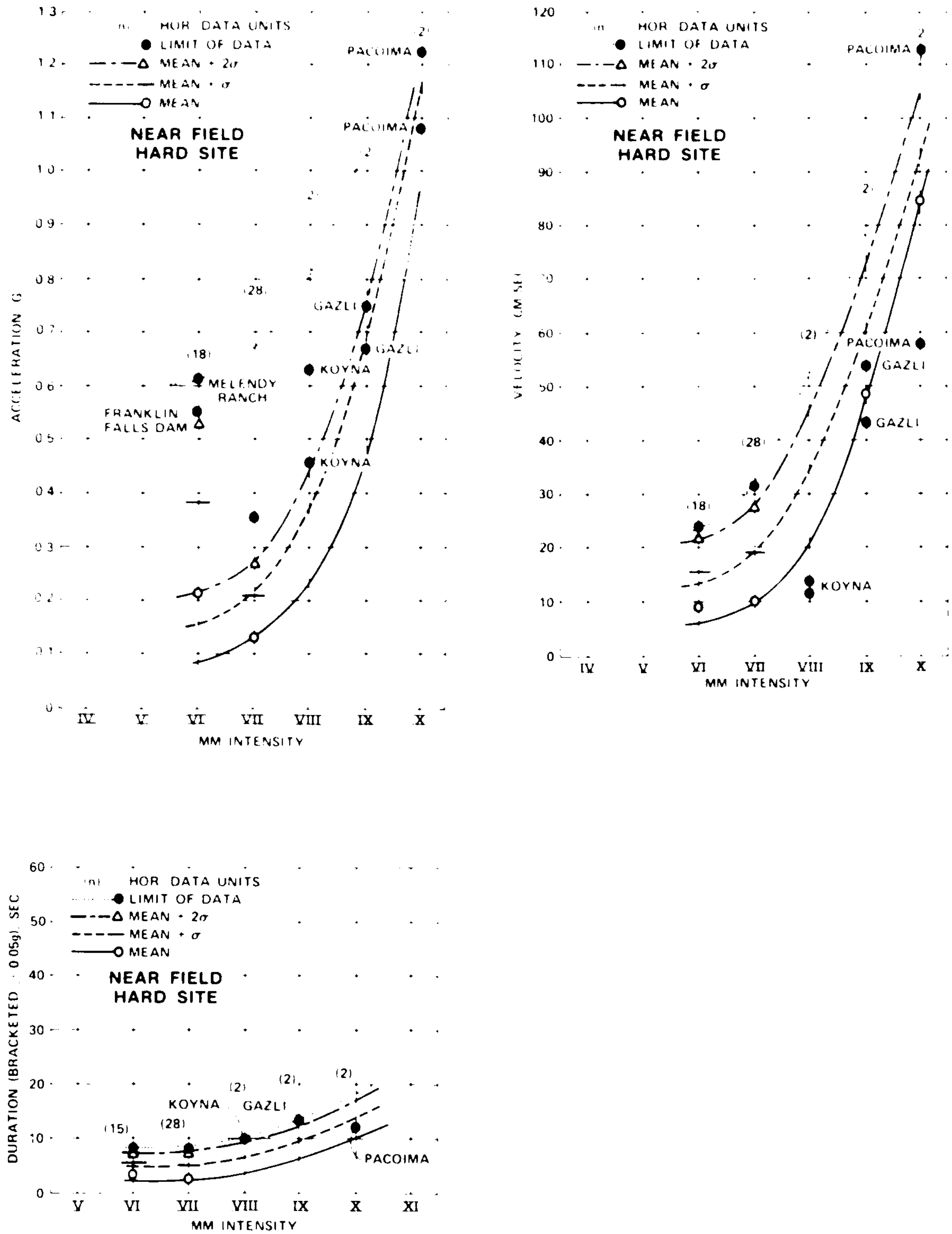


Figure 24. Acceleration, velocity, and duration for MM Intensity, Near Field, Hard Site. From Krinitzsky and Chang (in press).

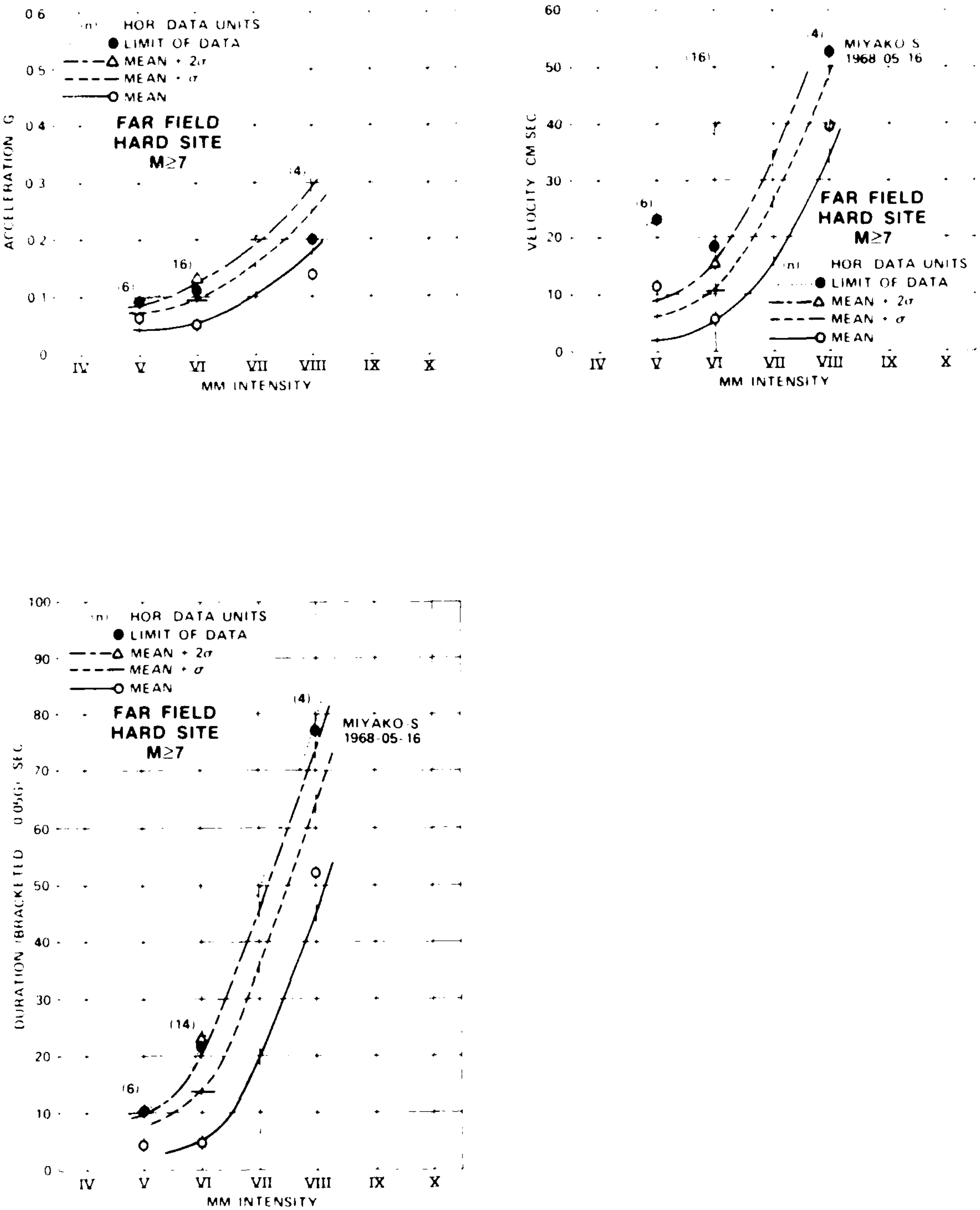


Figure 25. Acceleration, velocity, and duration for MM Intensity. Far Field, major earthquakes, Hard Site. From Krinitzsky and Chang (in press).

Accel, g: 0.68

Vel, cm/sec: 60

Dur, sec: 10

c. Far Source, Far Field at the Dam:

M_s = 7.5

MMI_s: I_o = X, reduced to I_s = VIII

Distance, km: 80

Site: Rock

Accel, g: 0.25

Vel, cm/sec: 48

Dur, sec: 65

Recommended Accelerograms

72. Four strong motion records were selected. These are tabulated in Table 4 along with their components of motion and scaling factors for adjusting their peak motions to motions for the recommended earthquakes. Two horizontal components of the Gazli, USSR, earthquake of 1976 are represented, one component each of the Pacoina record and Castaic record, San Fernando earthquake of 1979, and one component of the San Juan, Argentina, record of 1977. The latter record is on alluvium, but, at a distance of 80 km, alluvium may be taken as behaving in the same way as rock. Time histories and response spectra for these records are presented in Appendix A.

Operating Basis Earthquake

73. The operating basis earthquake at Blackfoot Dam cannot be related to probability of recurrence since the data are insufficient for calculating probabilities.

74. A reasonable alternative approach may be to relate the operating basis earthquake to the severest shaking felt at the site during the past 100 years. Table 3 shows that MM VI is the severest that has been experienced and that it resulted from large earthquakes ($M_s > 7.0$) at Far Field distances. Using the Krinitzsky-Chang charts in Figure 25, values are obtained as follows:

Accel, g: 0.10

Vel, cm/sec: 11

Dur, sec: 14

75. A more conservative approach is obtained if one uses half the values of the severest design earthquake, producing:

Accel, g: 0.34

Vel, cm/sec: 30

Dur, sec: 5

76. The use of these values is, however, a matter of engineering judgment.

Comparison of Motions

77. There are no nuclear power plants in the region.

78. Palisades Dam, 30 km from Blackfoot, is undergoing a reevaluation by the Bureau of Reclamation which at the time of this writing had not been completed. Preliminary motions* under consideration were:

a. Local earthquake: M_s = 6-6.5; distance, 3-10 km

Accel, g: 0.62

Vel, cm/sec: 34

Dur, sec: 12

Accelerogram used: Combination of Pacoina and Taft records, scaled to velocity at 50 cm/sec

b. Distant earthquake: M_s = 7.5; distance, 33 km

Accel, g: 27

Vel, cm/sec: 15

Dur, sec: 22

Accelerogram not specified.

79. Ririe Dam was evaluated by Patrick and Whitten (1981). Ririe Dam and Reservoir is about 65 km north of Blackfoot Dam and is near the edge of the Snake River Plain (see position in Figure 6). Thus Ririe may be affected by the aseismicity of the Snake River Plain, and not have as severe a local

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* Provided by J. Lawrence Von Thun on 4 October 1983, personal communication.

earthquake as at Blackfoot. Pirie, however, is less than [illegible] km from the zone of major faults in the Palisades graben. Thus, Pirie should be subject to motions comparable to the M_s = 7.5, 30 km distance, Near Field motions assigned to Blackfoot (acceleration 0.68 g, velocity [illegible] cm/sec, and [illegible] sec duration). It is also subject to a distant earthquake at 80 km (Far Field acceleration 0.25 g, velocity 48 cm/sec, and 65 sec duration).

8[illegible]. Patrick and Whitten (1981) recommended motions for severest shaking at acceleration 0.28 g, velocity [illegible] cm/sec, and [illegible] sec duration. It appears that these motions are too low.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

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Table 1

Description of Major Active Faults in the General Region of Blackfoot Reservoir. From Witkind (1975a, 1975b). See Figure 9.

Fault No.	Name	Latest Movement (Age)	Type	Relative Movement	Length	Earthquake Potential	Remarks
1	Wasatch Fault	Late Quaternary	High angle normal	West side down	Major	High-probably major eqk (7+)	Many scarps, 1/4 mile each side of main scarp. Northern edge of Wasatch fault.
2	Cache Valley Fault (West Cache Fault)	Probably latest Quaternary (faulting older than Wasatch)	High angle normal north trending fault	East side down	Many miles	Great	Many small scarplets, 1/4 mile each side.
3	Clifton-Oxford Fault	Late Quaternary	High angle normal	East side down	About 8 miles	Great	Many small scarplets and branches.
16	Rock Creek Fault	Historic-100 years old	High angle normal	Down-thrown on west	24-25 miles	High	One scarp. Indications that fault has moved in past 100 years. Scarps 50-60 ft in alluvium.
17	En Echelon Series of faults	Late Cenozoic	High angle normal	Down-thrown on west	25 miles +	Low to moderate	En Echelon Series
18	Unnamed fault, west side of Sublette Ridge	Late Cenozoic	High angle normal	Down-thrown valley-side (west side down)	45 miles ±	High	No modern movement. Connects with fault in UT along west front of Crawford Mountains.

(Continued)

(Sheet 1 of 6)

Table 1 (Continued)

Fault No.	Name	Latest Movement (Age)	Type	Relative Movement	Length	Earthquake Potential	Remarks
19	Unnamed fault, west side Bear River Valley, east side Boundary Ridge, west of Cokeville	Late Cenozoic	High angle normal	East side (valley) down-thrown	About 10 miles	Low to moderate	No modern scarplets.
20	Star Valley Faults (North Star Valley Fault) determine west flank of Salt River Range	Cuts Holocene beds	High angle normal	West side (valley) down-thrown	Many miles	High	Modern scarplets. This fault connects with North Swan Valley fault.
21	Star Valley Faults (South Star Valley Fault)	Cuts Holocene beds	High angle normal	West side (valley) down-thrown	± 18 miles	High	Modern scarplet.
22	Grand Valley Fault	Late Cenozoic	High angle normal	South-west block down (valley side down)	Joins Star Valley fault (No. 20)	High	No scarplets, Seismic activity related to Palisades Reservoir.
24	East side, Bear Lake	Late Quaternary, major movement	High angle normal	West side down	55 to 60 mi. at least	High	Discontinuous fault, extends to Blackfoot Reservoir. Breaks basalt there at least 50,000 yrs old.

(Continued)

(Sheet 2 of 6)

Table 1 (Continued)

Fault No.	Name	Latest Movement (Age)	Type	Relative Movement	Length	Earthquake Potential	Remarks
25	West side of Bear Lake	Probably major Late Quaternary	High angle normal	East side down-thrown	En Echelon Series of short breaks (55-60 miles)		Extends as far north as Blackfoot Reservoir.
26	Unnamed fault east of Franklin	Major Late Quaternary?	High angle normal, east side of basin	West side down-thrown			This is a major fault bounding the east flank of Cache Valley.
27	Clifton Hill Fault	Probably Late Cenozoic	High angle normal	North-east side (valley down-thrown	About 8 miles	Low	
31	Unnamed faults along west side of Samaria Mtn	Holocene	High angle normal	West side down Pocatello Valley (not near Pocatello ID)	6-8 miles	High	Two faults.
32	East Gem Valley Fault	Late Cenozoic	High angle normal	West side (Gem Valley) down-thrown	28-30 miles	Low to moderate	No breaks in surface deposits.

(Continued)

(Sheet 3 of 6)

Table 1 (Continued)

Fault No.	Name	Latest Movement (Age)	Type	Relative Movement	Length	Earthquake Potential	Remarks
33	West Gem Valley Fault	Late Cenozoic	High angle normal	North-east side (Gem Valley down-thrown)	22-25 miles		
34	Teton normal fault	Pleistocene and Recent movement	High angle normal	East block down	40 miles	High	Some small scarplets cut Pinedale (150-200 ft high).
35	Hoback normal fault	Pleistocene deposits cut Holocene	High angle normal	South-west block down	35 miles		Scarplets in loess and silt. Scarplets about 50 ft high.
57	Unnamed-east side of Deep Creek Mountains	Late Cenozoic	High angle normal, dips valley-ward, east side down	East side down-thrown	40 miles	Low to moderate	
58	East side of Bannock Creek Valley	Late Cenozoic	High angle normal, dips valley-ward	West side down-thrown	12 miles	Low to moderate	

(Continued)

(Sheet 4 of 6)

Table 1 (Continued)

Fault No.	Name	Latest Movement (Age)	Type	Relative Movement	Length	Earthquake Potential	Remarks
59	East side Arbon Valley	Late Cenozoic	High angle normal, dips valley-ward	North-west side down-thrown	40-45 miles	Low to moderate	No mapping done in this general area.
60	Woodruff fault, north edge of Samaria Mountains	Probably major: Late Quaternary	High angle normal	Down-thrown on north	About 7 miles		May be strike-slip.
61	Unnamed fault, west side Bannock Range	Late Cenozoic	High angle dipping valley-ward	West side down-thrown	8 miles ±		
62	Unnamed in-ferred fault, west side of Rattlesnake Creek Valley	Late Cenozoic	High angle normal, dips valley-ward	East side down-thrown	About 8 miles	Low to moderate	
63	Unnamed fault, west side Marsh Creek valley	Late Cenozoic-Pliocene	High angle normal, dips valley-ward	East block down-thrown	32 miles ±	Low to moderate	

(Continued)

Table 1 (Concluded)

Fault No.	Name	Latest Movement (Age)	Type	Relative Movement	Length	Earthquake Potential	Remarks
64	Unnamed fault, Rapid Creek Fault?	Late Cenozoic-Pliocene	High angle normal, dips valley-ward	East side down-thrown	About 8 miles	Low	
65	Unnamed fault, along east side of Marsh Creek	Late Cenozoic-Pliocene	High angle normal, dips valley-ward	South-west block down-thrown	65 miles	Moderate	
84	Enoch Valley Fault (En Echelon Series)	Probably Late Cenozoic	High angle normal	South-west flank down	30 miles		
85	Lime Rock Fault (En Echelon Series)	Probably Late Cenozoic	High angle normal	North-east block down	About 30 miles		
86	Unnamed fault, east side of Little Gray Ridge	Probably Late Cenozoic	High angle normal	South-west side down-thrown	13 miles (En Echelon)		
98	Herse Fault	Major Late Quaternary	High angle normal	North-east block downthrown	20-21 miles	Low to moderate	
234	Unnamed	Late Cenozoic	High angle normal	Down on north			

(Sheet 6 of 6)

Table 2

Characteristics of Hot Springs in the Blackfoot Area (see Figure 14)
From Mitchell, Johnson and Anderson ([illegible])

County	Map Location	Spring/Well Identification No. and Name	Discharge (l/min)	Aquifer Age and Rock Type	Geologic Structure	Remarks	Deposition: Gas	Deposition: Siliceous	Deposition: Carbonates	Well Depth (m)	Surf. Temp. (°C)	Aquifer Temp. (°C)
Bannock	13	Lava Hot Springs 9S 38E 21DDA1S		Paleozoic quartzite and younger travertine	Fault	Numerous spring vents, extensive travertine deposition	Yes		Yes		45	50
Bannock	14	Lava Hot Springs 9S 38E 22CCB1S		Paleozoic quartzite					Yes		45	50
Bear Lake	17	Pescadero WS 11S 43E 36BDA1S	37	Paleozoic limestone		Three spring vents in quite extensive travertine deposits					26	69
Bingham	1	Alkali Flats WS 4S 38E 38DDD1S	37	Tufa in Quaternary alluvium			Yes				3	405
Bonneville	2	Brockman Creek WS 2S 42E 26DCD1S	49								35	
Bonneville	3	Alpine WS 2S 46E 19CAD1S	94	Quaternary alluvium near tertiary silicic volcanics		Spring is now under Palisades Reservoir					37	61
Caribou	4	Blackfoot River WS 5S 40E 14BCD1S	3	Quaternary basalt							26	52
Caribou	5	Wilson Lake WS 5S 41E 6ABB1S				Not field checked; reported to have several spring vents					30	
Caribou	6	Corral Creek Well #1 6S 41E 19BAA1	598	Permian phosphatic shale		Travertine deposits	Yes			39	42	45
Caribou	7	Corral Creek Well #2 6S 41E 19BAB1	39[illegible]	Permian phosphatic shale		Travertine deposits	Yes			36	41	48
Caribou	8	Corral Creek Well #3 6S 41E 19BAC1	79	Permian phosphatic shale		Travertine deposits	Yes			56	41	48
Caribou	9	Corral Creek Well #4 6S 41E 19BAD1		Permian phosphatic shale		Travertine deposits	Yes			64	36	48
Caribou	10	Blackfoot Reservoir 6S 41E 1ADC1S	567	Quaternary Tufa							22	40
Caribou	11	Henry WS 6S 42E 8DBA1S		Quaternary Tufa							30	
Caribou	12	Portneuf River WS 7S 38E 26CBD1S		Quaternary basalt (?)							34	
Caribou	15	Steamboat Springs 9S 41E 10DAA1S				Submerged in Soda Point Reservoir					31	
Caribou	16	Soda Springs Geyser 9S 41E 1[illegible]	3	Holocene travertine near Pleistocene basalt	Northwest trending thrust fault		Yes		Yes		28	56

Table 3

Major Earthquakes Felt at Blackfoot Damsite

Year	Date	Locality	Lat.	Long.	Area sq. mi.	I_o	Distance to Site, km	I_s	M
1894	Jul 18	Ogden, UT	41.2	112.0	(L)	VI-VII	202	III-IV	--
1905	Nov 11	Shoshone, ID	42.9	114.5	--	VII	227	IV	--
1909	Oct 5-Dec	UT	42.0	113.0	(L)	VII	154	V	--
1914	May 13	UT	42.0	112.0	8,000	VII	114	V	--
1916	May 12	Boise, ID	43.7	116.2	50,000	VII	373	III	--
1925	Jun 27	S.E. of Helena, MT	46.0	111.2	310,000	VIII	336	IV	6-3/4
1934	Mar 12	Kosmo, UT	41.7	112.8	170,000	VIII	171	V	6.6
1934	Mar 12	Kosmo, UT	41.7	112.8	170,000	VIII	171	V	6.0
1935	Oct 12	Helena, MT	46.6	112.0	70,000	VII	401	III	--
1935	Oct 18	Helena, MT	46.6	112.0	230,000	VIII	401	IV	6-1/4
1935	Oct 31	Helena, MT	46.6	112.0	140,000	VIII	401	IV	6
1944	Jul 12	Seafoam, ID	44.7	115.2	70,000	VII	338	III	--
1947	Nov 23	S. W. MT	44.8	112.0	150,000	VIII	202	V	6-1/4
1952	Mar 31	N.W. MT	48.0	113.8	35,000	VII	508	III	--
1959	Aug 17	Hebgen Lake, MT	44.8	111.1	600,000	X	206	V	7.1
1959	Aug 18	Yellowstone N.P. (Aftershock of Aug 17)	44.8	110.7	--	VI	217	III	6.0
1962	Aug 30	Northern UT	41.8	111.8	65,000	VII	134	IV	--
1969	Apr 1	N.W. MT	47.9	114.3	10,000	VII	582	II	--
1975	Mar 28	Eastern ID	42.1	112.5	61,760	VIII	119	VI	6.1
1975	Jun 30	Yellowstone N.P.	44.7	110.6	19,300	VII	210	IV	6.4
1983	Oct 28	S.E. ID	44.05	113.89		X	220	VI	7.3

(L) Local Earthquake

* Personal Communication, Natl. Eqk. Inf. Cent., Waverly Person, 1-3-84

Table 4

Strong Motion Records and Components of Motion for Earthquakes at Blackfoot Dam

[illegible] Earthquake	Selected Strong Motion Record	Site	Instr. Comp.	A_p cm/sec^2	V_p cm/sec	MM I_s	Dur sec	Scaling Factor	Modified A	Modified V cm/sec	Epicentral Dist. km
1. Near Field at Dam M = 6.5, I_s = IX A = [illegible] g V = [illegible] cm/sec Dur = [illegible] sec	Gazli, U.S.S.R. May 17, 1976	Rock	NS EW	609.22 716.66	67.22 57.74	IX	13.5 13.0	0 0			Vicinity
	San Fernando, Pacoima, [illegible] (C.I.T.: [illegible])	Rock	S16°E (Corr. S14°W)	1148.1 (1.17 g)	113.2	X	11.36	0.58	0.68 g	65	Vicinity
2. Near Field at [illegible] km M = [illegible], I_s = IX A = [illegible] g V = [illegible] cm/sec Dur = [illegible] sec	San Fernando, Oak Ridge Route, Castaic, [illegible] (C.I.T.: D056)	Hard	N69°W	265.4 (0.27 g)	27.2	VI	19	2.5	663.5 (0.68 g)	68	30 km
3. Far Field at 8[illegible] km M = 7.5, I_s = VIII A = 0.25 g V = 48 cm/sec Dur = 65 sec	San Juan, Argentina Nov. 23, 1977	Alluvium	EW	189.5	20.6	VIII	48	2.3	435.9 (0.45 g)	47	70 km

APPENDIX A

FELT EARTHQUAKES IN THE GENERAL REGION OF BLACKFOOT DAM
(INTENSITY MM IV OR GREATER OR INSTRUMENTALLY LOCATED)

Area Coordinates 109.5-114.0 degrees Long.
41.0- 45.0 degrees Lat

From Earthquake History of the United States, Edited by
Coffman, von Hake and Stover, 1982

Year	Date	Time MST	Locality	Coordinates Deg. N. Lat.	Deg. W. Long.	Intensity MM	Magnitude	Felt Area (sq mi)
1880	11 Jul	2200	Portage, Utah	42.0	112.3	VI	(5.0)	
1906	18 Oct	1906	Idaho	42.5	111.4	V		3,000
1913	12 Apr	0125	SE Idaho	42	112	V		8,000
1914	13 May	1015	SE Idaho	42	112	VII	(5.5)	8,000
1915	30 Jul	1150	N. Utah	41.8	112.2	V	(4.0)	
1916	12 May	1930	Boise, Idaho	43.7	116.2	VII		50,000
1917	12 Dec	0500	S. Idaho	43.0	111.3	V		8,000
1923	23 Mar-12 Apr	2100	Kelly, Wyoming	43.6	110.6	V		1,500
1924	25 Nov	0710	SE Idaho	42.5	111.5	V		20,000
1930	12 Jun	0215	Grover, Wyoming	42.6	111.0	VI	(5.0)	
1930	24 Aug-22 Dec	various	Yellowstone N. P., Wyoming	44	111	IV-V		
1932	26 Jan	0313	W. Wyoming	43.6	110.8	V-VI	(5.0)	1,000
1933	2 Nov	0926	Gray, Idaho	43.0	111.3	V		
1936	14 Jan	2140	Yellowstone N. P., Wyoming	44	111	VI	(5.0)	1,200
1942	5 Aug	1434	Yellowstone N. P., Wyoming	44	111	V		
1946	5 May	2130	N. Utah	41.8	112.0	V		
1947	23 Nov	0246	SW Montana	44.8	112.0	VIII	M = 6.2	150,000
1948	23 Feb	1939	NW Wyoming	43.5	111.0	VI	(5.0)	1,500
1950	27 Jun	2131	W. Yellowstone, Montana	44 3/4	110 1/2	VI	5.0	
1954	4 Jul	0933	Yellowstone N. P., Wyoming	44.9	110.8	V		
1958	28 Apr	1359	Yellowstone N. P., Wyoming	44	111	V		
1959	17 Aug	2337	Hebgen Lake, Mont.	44.8	111.1	X	M = 7.1	600,000
1959	18 Aug	0142	Yellowstone N. P., Wyoming	44.8	110.7	VI	M = 6.0	
1959	18 Aug	2104	SW Montana	44.9	111.6	V	M = 6.0	
1959	30 Aug	0050	W. Yellowstone, Mont.	44.7	111.1	V		

(Continued)

(Sheet 1 of 6)

Year	Date	Time MST	Locality	Coordinates Deg. N. Lat.	Deg. W. Long.	Intensity MM	Magnitude	Felt Area (sq mi)
1959	5 Sep	0510	Yellowstone N. P., Wyoming	44 3/4	111	VI	M = 5.0	
1959	25 Sep	0540	Yellowstone N. P., Wyoming	44 3/4	111	V		
1959	26 Sep	0204	Yellowstone N. P., Wyoming	44 3/4	111	V		
1959	18 Oct	0509	West Yellowstone, Mont.	44.7	111.1	V		
1959	19 Oct	0200-0650	West Yellowstone, Mont.	44.7	111.1	V		
1959	4 Nov	2142	Yellowstone N. P., Wyoming	44 3/4	111	V		
1959	11 Dec	2323	W. Yellowstone, Mont.	44.7	111.1	V		
1959	12 Dec	1047	W. Yellowstone, Mont.	44.7	111.1	V		
1959	13 Dec	0057	Yellowstone N. P., Wyoming	44 3/4	111	V		
1960	4 Jan	2104	Hebgen Lake, Mont.	44 1/2	111 1/2	V		
1960	22 Mar	2015	Hebgen Lake, Mont.	44 1/2	111	V		
1960	26 Apr	2132	Hebgen Lake, Mont.	44 1/2	111	V		
1960	7 Aug	0927	SE Idaho	42.4	111.5	VI	(5.0)	900
1960	10 Aug	0042	SE Idaho	42.5	111.5	V		
1960	20 Aug	0102	SE Idaho	42.3	111.3	V		
1961	13 Mar	1228	Hebgen Dam, Mont.	44.9	111.4	V		
1961	6 Apr	2251	S. Madison Co., Mont.	44.8	112.0	V		2,500
1961	29 Jun	0445	Yellowstone N. P., Wyoming	44 3/4	111	V		
1962	30 Aug	0635	N. Utah	41.8	111.8	VII	(5.5)	65,000
1962	4 Sep	2000	Logan, Utah	41.7	111.8	V		
1962	7 Sep	AM	Lewiston, Utah	42	111.8	V		

(Continued)

Year	Date	Time MST	Locality	Coordinates Deg. N. Lat.	Deg. W. Long.	Intensity MM	Magnitude	Felt Area (sq mi)
1963	8 Mar	0136	Yellowstone N. P., Wyoming	44.8	110.2	VI	M = 3.8	
1963	21 Mar	2135	Yellowstone N. P., Wyoming	44.8	110.5	V	M = 4.3	
1963	18 Apr	0343	Yellowstone N. P., Wyoming	44.8	110.3	V		
1963	23 Sep	2336	Yellowstone N. P., Wyoming	44.9	111.0	V	M = 3.1 M = 4.7	
1963	17 Dec	0230	Yellowstone N. P., Wyoming	44.9	111.0	V		
1963	20 Dec	0601	Hebgen Lake, Mont.	44.9	111.7	V	M = 4.3	3,000
1964	21 Oct	0039	Hebgen Lake, Mont.	44.8	111.6	V	M = 5.8	25,000
1965	5 Jan	1901	SW Montana	44.9	112.7	VI	M = 5.1	12,000
1965	12 Jan	2044	E. Idaho	44.9	112.7	V		
1965	8 Oct	1235	Hebgen Lake, Mont.	44.8	111.1	V	M = 4.9	
1966	11 Oct	0030	Hebgen Lake, Mont.	44.9	111.1	V	M = 4.0	
1966	11 Oct	0448	W. Yellowstone, Mont.	44.7	111.1	V		
1966	11 Oct	1053	Hebgen Lake, Mont.	44.8	111.2	V	M = 4.3	
1971	16 Jul	0354	E. Idaho	42.2	111.4	V	m_b = 3.6	
1972	6 Mar	0633	Utah-Idaho Border	41.9	111.6	V	—	
1972	23 Nov	2236	E. Idaho	42.5	111.2	IV	—	
1974	30 Aug	1641*	Yellowstone N. P., Wyoming	44.70	110.8	V	m_b = 4.5 M_L = 4.5	
1974	22 Oct	0843*	Yellowstone N. P., Wyoming	44.74	110.81	IV	m_b = 4.6	
1974	28 Dec	1357*	Idaho-Utah Border	42.00	111.97	IV	M = 2.8	
1975	27 Mar	0448*	E. Idaho	42.07	112.55	V	m_b = 4.4	
1975	28 Mar	0231*	E. Idaho	42.06	112.55	VIII	m_b = 6.1	160,000
1975	28 Mar	1311*	E. Idaho	42.05	112.48	IV	m_b = 4.3	
1975	29 Mar	0544*	E. Idaho	42.08	112.45	IV	m_b = 4.3	

(Continued)

* Greenwich Mean Time.

Year	Date	Time MST	Locality	Coordinates Deg. N. Lat.	Coordinates Deg. W. Long.	Intensity MM	Magnitude	Felt Area (sq mi)
1975	29 Mar	1301*	E. Idaho	42.02	112.52	V	m_b = 4.7	
1975	30 Jun	1854*	Yellowstone N. P., Wyoming	44.75	110.61	VII	m_b = 5.6	50,000 km^2
1975	5 Jul	1917*	Yellowstone N. P., Wyoming	44.71	110.62	IV	m_b = 4.5	
1975	13 Jul	1001*	Yellowstone N. P., Wyoming	44.71	110.67	IV	m_b = 4.4	
1975	22 Sep	1042*	E. Idaho	42.08	112.45	IV	m_b = 4.2	
1976	14 Jun	0937*	E. Idaho	42.12	112.48	IV	M_L = 3.6	
1976	19 Oct	0618*	Yellowstone N. P., Wyoming	44.74	110.81	IV	m_b = 5.3	
1976	19 Oct	0724*	Yellowstone N. P., Wyoming	44.80	110.70	IV	m_b = 5.3	
1976	5 Nov	0248*	N. Utah	41.81	112.70	V	M_L = 4.1	
1976	17 Nov	1434*	Yellowstone N. P., Wyoming	44.75	110.86	IV	M_L = 3.7	
1976	27 Nov	0024*	Hebgen Lake, Mont.	44.64	111.14	IV	M_L = 3.7	
1976	8 Dec	1440*	Yellowstone N. P., Wyoming	44.76	110.79	V	m_b = 5.5	
1976	9 Dec	2236*	Yellowstone N. P., Wyoming	44.77	110.80	V	m_b = 4.5	
1976	16 Dec	0028*	Yellowstone N. P., Wyoming	44.64	110.05	IV	M_L = 3.0	
1976	19 Dec	1710*	Yellowstone N. P., Wyoming	44.77	110.80	VI	m_b = 4.9	
1976	20 Dec	0134*	Yellowstone N. P., Wyoming	44.84	110.83	IV	m_b = 4.4	
1977	4 Mar	1300	Hebgen Lake, Mont.	44.80	111.08	IV	m_b = 4.1	
1978	2 Feb	0036	Yellowstone N. P., Wyoming	44.39	110.81	III	m_b = 3.6	
1978	2 Feb	1235	Yellowstone N. P., Wyoming	44.38	110.83	III	m_b = 3.3	

(Continued)

* Greenwich Mean Time.

				Coordinates				
Year	Date	Time MST	Locality	Deg. N. Lat.	Deg. W. Long.	Intensity MM	Magnitude	Felt Area (sq mi)
1978	7 Feb	05-3	Southwestern Wyoming	42.50	109.70		m_b = 3.7	
1978	25 Feb	2122	East Central Idaho	44.64	113.80			
1978	7 Mar	0110	Yellowstone N. P., Wyoming	44.34	110.84	V	m_b = 3.7	
1978	7 Mar	0739	Yellowstone N. P., Wyoming	44.30	110.92	IV	m_b = 3.8	
1978	10 Mar	0747	NW Wyoming	43.80	110.18		M_L = 3.2	
1978	15 Apr	0523	Western Wyoming	42.72	110.88	II	M_L = 2.5	
1978	20 Apr	1456	Southeastern Idaho	42.66	111.55	IV	M_L = 2.5	
1978	29 Jul	1404	Northern Utah	41.85	112.13	IV	M_L = 3.1	
1978	15 Sep	1345	Yellowstone N. P., Wyoming	44.56	110.49	IV	M_L = 2.5	
1978	28 Sep	0858	Southern Idaho	42.10	112.33	IV	M_L = 2.7	
1978	24 Oct	2030	Southeastern Idaho	42.55	111.84	VI	m_b = 4.2	
1978	30 Nov	0653	Southeastern Idaho	42.11	112.49	V	m_b = 4.6	
1978	30 Nov	1155	Southeastern Idaho	42.11	112.55	II	M_L = 3.5	
1978	5 Dec	1124	Southeastern Idaho	42.10	112.48		M_L = 3.7	
1978	5 Dec	1156	Southeastern Idaho	42.10	112.54		M_L = 3.0	
1978	20 Dec	1346	Southeastern Idaho	42.12	112.49	IV	M_L = 3.9	
1979	5 Jan	1408	Yellowstone Lake	44.40	110.27		M_L = 3.5	
1979	24 Feb	1243	Southwestern Wyoming	41.65	111.00		M_L = 3.5	
1979	25 Mar	2141	Northwestern Utah	41.34	113.29	Felt	M_L = 3.2	
1979	3 Jun	0458	Southeastern Idaho	42.51	111.36	IV	M_L = 3.7	
1979	3 Jul	0957	Northwestern Wyoming	43.41	110.71	IV	M_L = 3.2	
1980	20 Feb	1207	Yellowstone N. P., Wyoming	44.84	110.89			
1980	20 Feb	1207	Yellowstone N. P., Wyoming	44.80	110.92	IV	M_L = 3.3	
1980	21 Feb	0639	East Central Idaho	44.40	112.98		M_L = 3.0	
1980	22 Feb	1018	Yellowstone N. P., Wyoming	44.81	110.90	IV	m_b = 4.5	
1980	27 Feb	0605	Yellowstone N. P., Wyoming	44.76	111.04	IV	M_L = 3.4	

(Continued)

(Sheet 5 of 6)

Year	Date	Time MST	Locality	Coordinates Deg. N. Lat.	Deg. W. Long.	Intensity MM	Magnitude	Felt Area (sq mi)
1980	29 Feb	1933	Southeastern Idaho	42.72	111.73	IV	$M_L = 3.3$	
1980	10 Mar	2028	Southeastern Idaho	42.44	111.28		$M_L = 3.3$	
1980	4 Apr	0045	Northwestern Utah	41.34	113.31	IV	$M_L = 3.0$	
1980	4 Apr	0056	Northwestern Utah	41.35	113.32	Felt	$M_L = 2.7$	
1980	9 Aug	0450	Yellowstone N. P., Wyoming	44.44	110.54	IV		
1980	9 Aug	0452	Yellowstone N. P., Wyoming	44.43	110.54	IV		
1980	9 Aug	0518	Yellowstone N. P., Wyoming	44.44	110.54	IV		
1980	15 Aug	0625	Northeastern Utah	41.66	111.66		$M_L = 2.9$	
1980	18 Oct	2145	Yellowstone N. P., Wyoming	44.65	110.52	III	$M_L = 2.7$	
1980	18 Oct	2157	Yellowstone N. P., Wyoming	44.64	110.52	III	$M_L = 2.7$	
1980	14 Nov	2108	Yellowstone N. P., Wyoming	44.59	111.04	III	$M_L = 3.2$	
1983	28 Oct*		SE Idaho	44.05	113.89		MS = 7.3	

(Sheet 6 of 6)

* National Earthquake Information Center, 1/3/84

APPENDIX B

SELECTED ACCELEROGRAMS AND RESPONSE SPECTRA:

(1) Gazli, U.S.S.R., earthquake of May 17, 1976: N-S and E-W Components.*

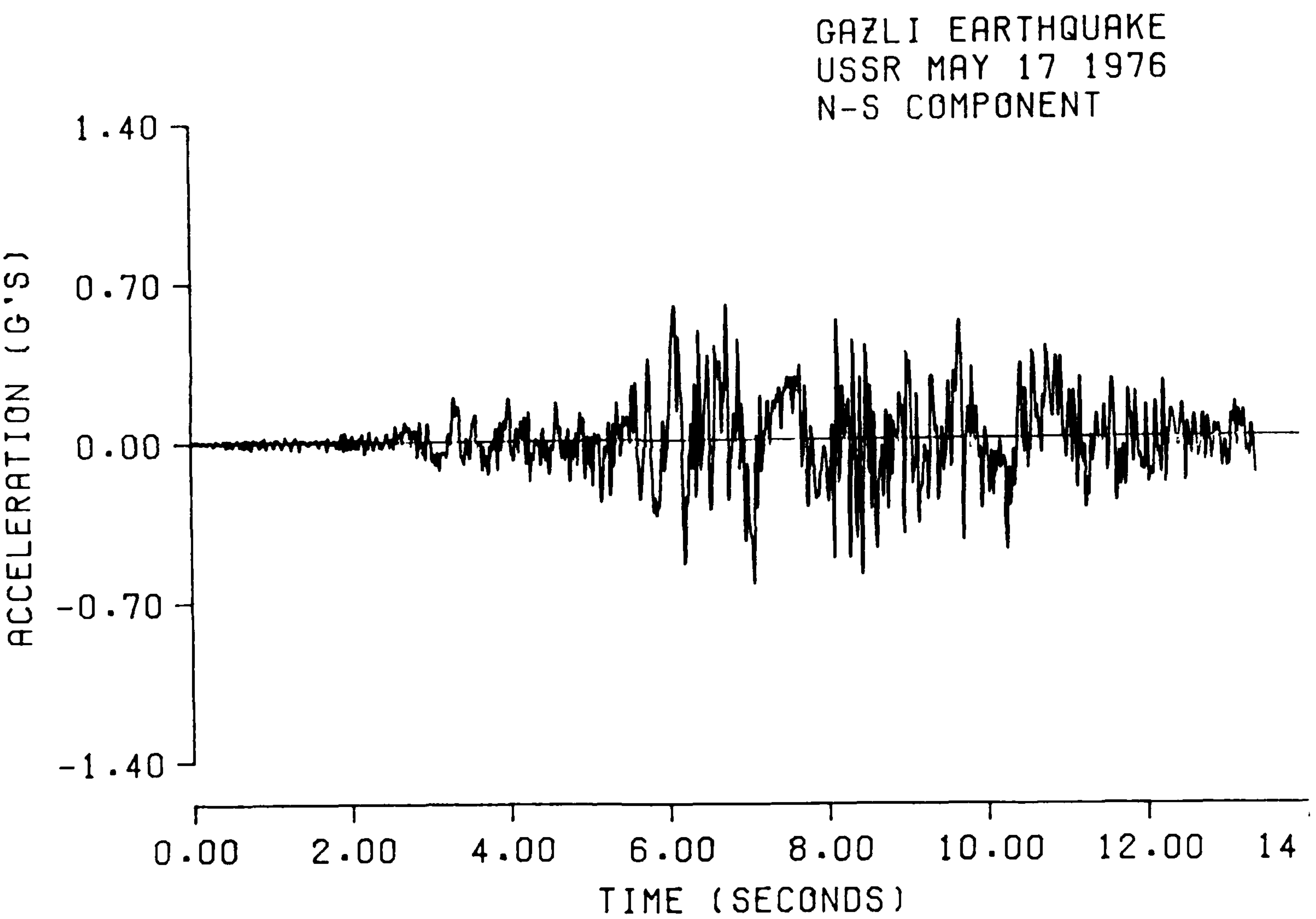
(2) San Fernando, U.S.A., earthquake of October 15, 1979: Pacoima, S-W Component.**

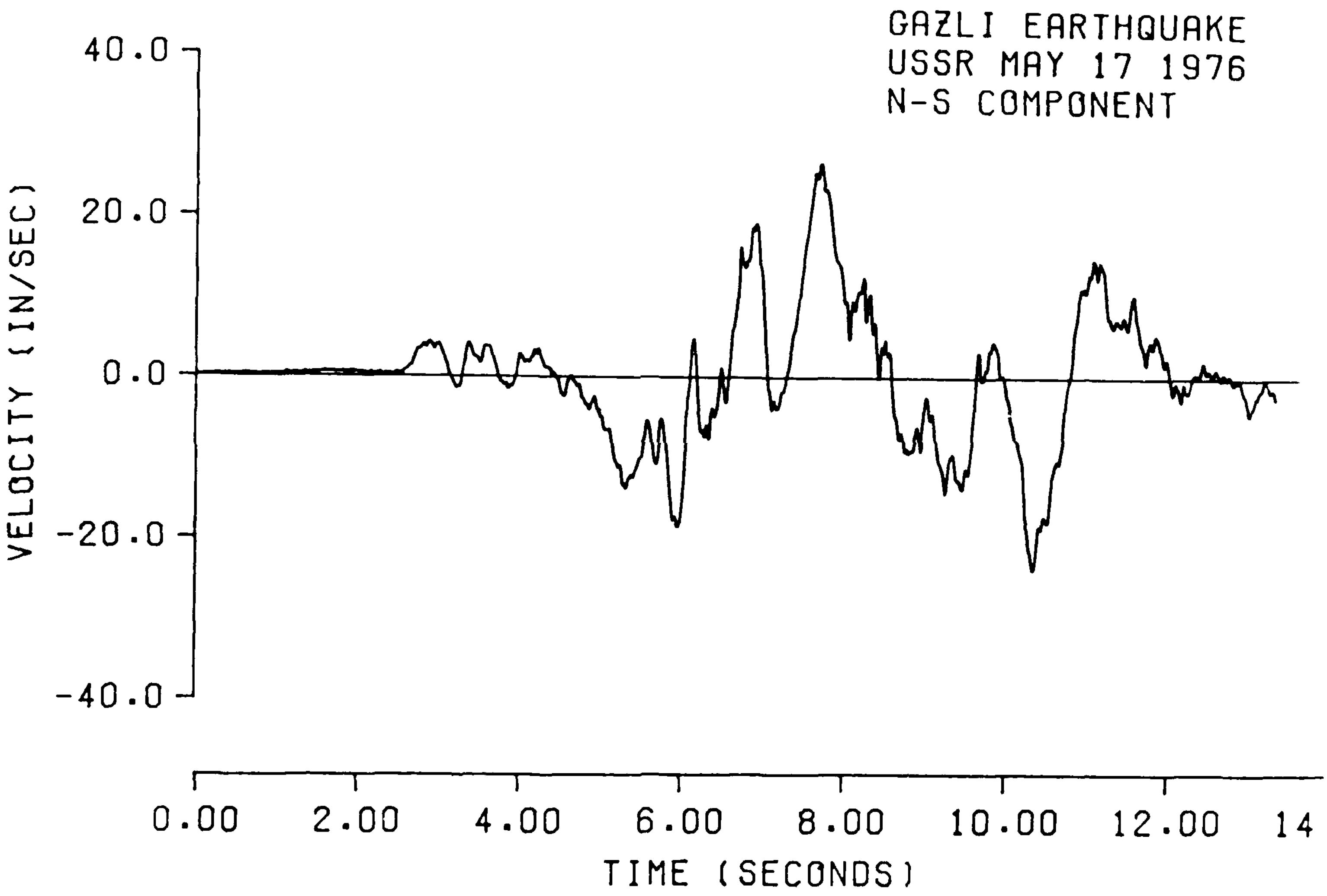
(3) Same: Castaic, N-W Component.**

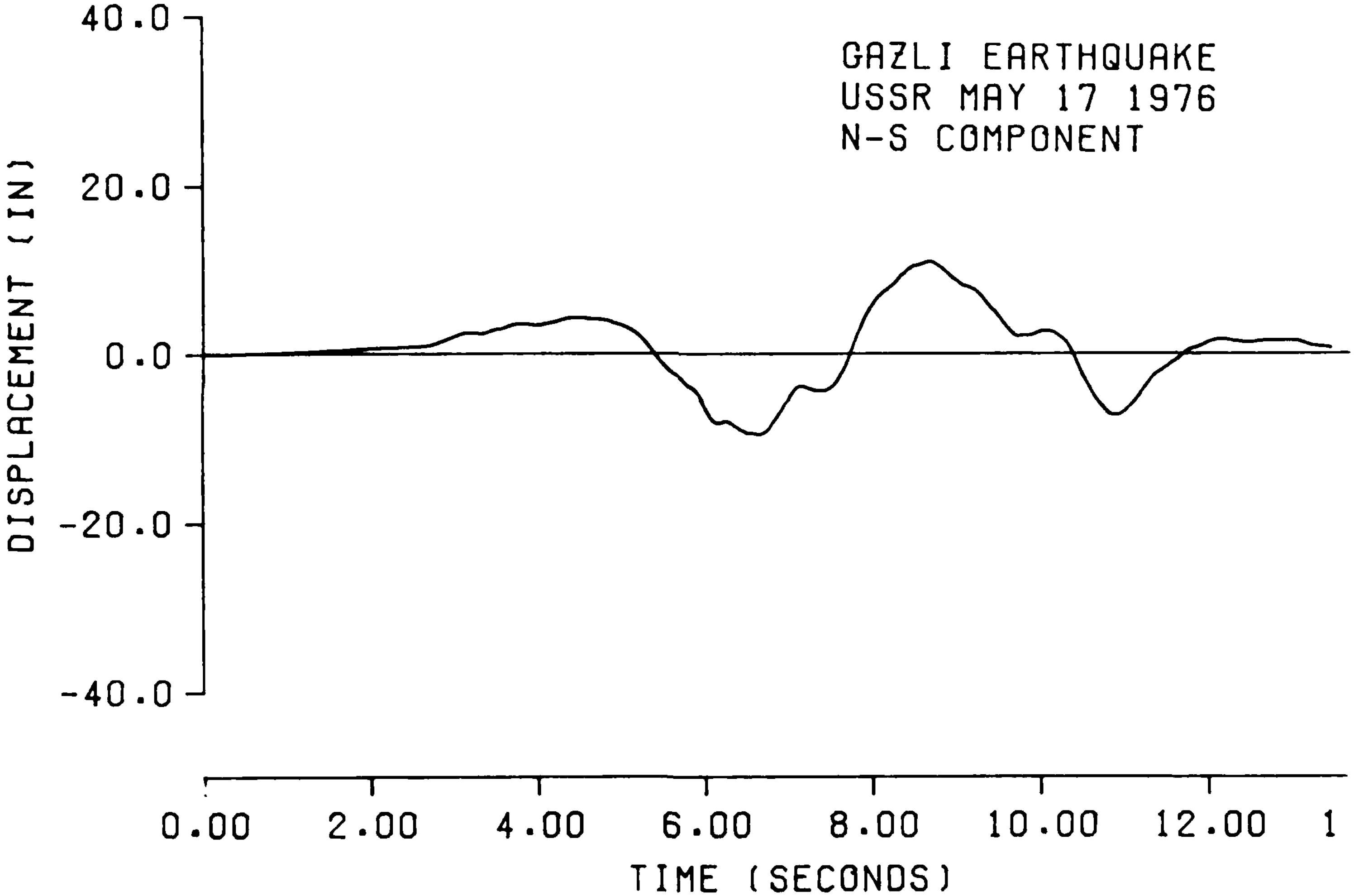
(4) San Juan, Argentina, earthquake of November 23, 1977: E-W Component.*

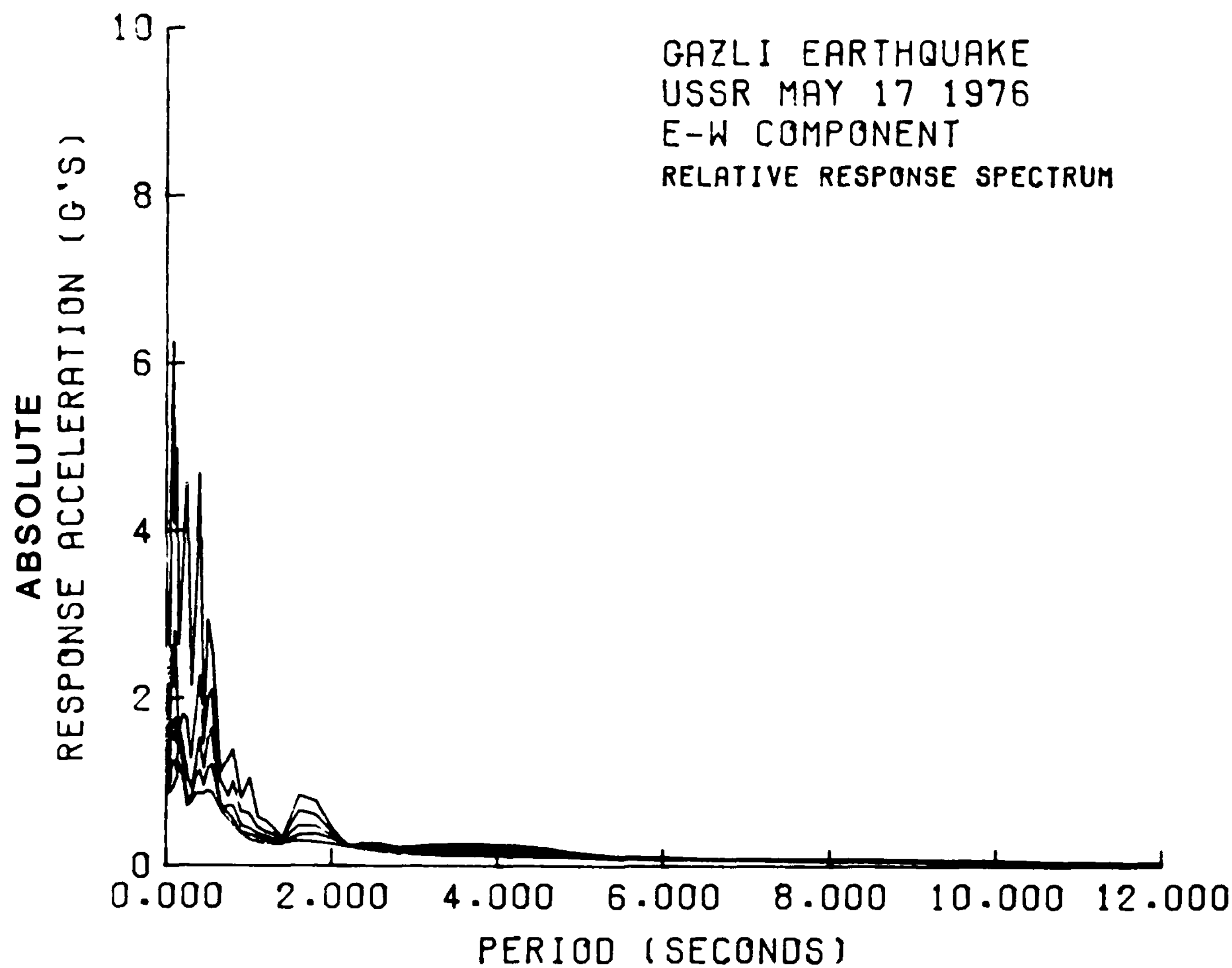
* Obtained from U. S. Geological Survey, Menlo Park, California.

** California Institute of Technology (1971-1975).

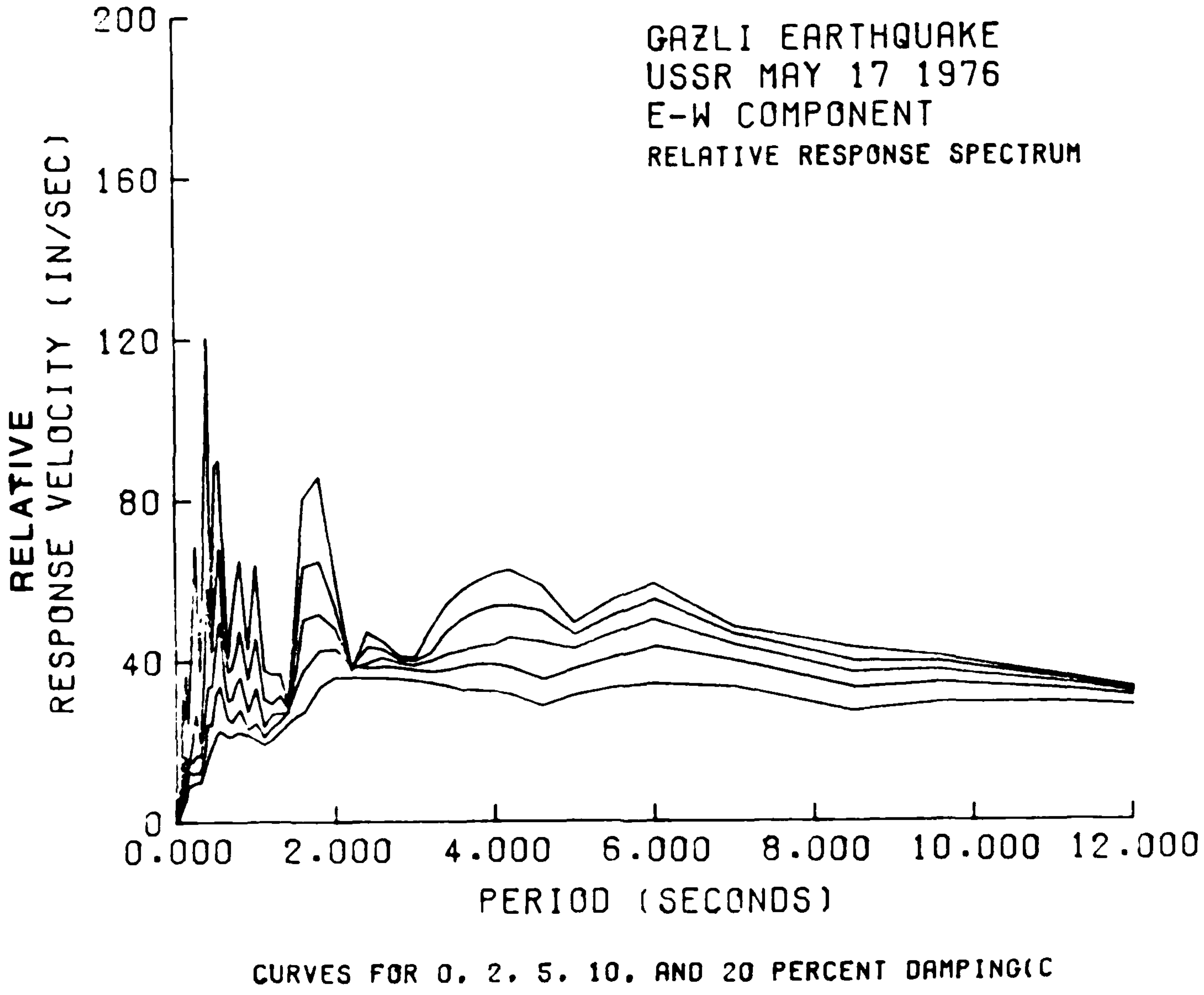

GAZLI EARTHQUAKE
USSR MAY 17 1976
N-S COMPONENT
1.40
0.70
0.00
-0.70
-1.40
ACCELERATION (G'S)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14
TIME (SECONDS)

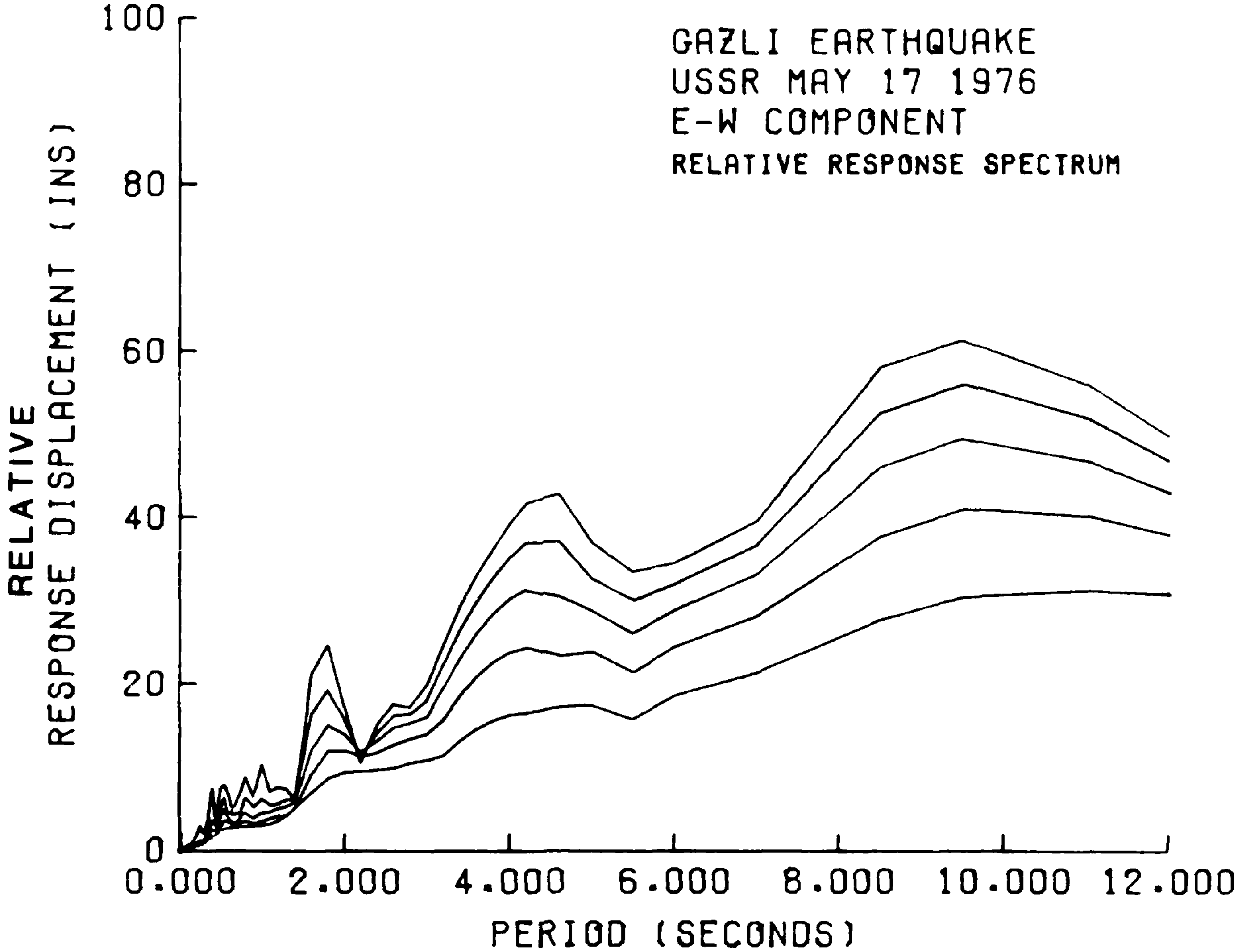

GAZLI EARTHQUAKE
USSR MAY 17 1976
N-S COMPONENT
40.0
20.0
0.0
-20.0
-40.0
VELOCITY (IN/SEC)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14
TIME (SECONDS)


GAZLI EARTHQUAKE
USSR MAY 17 1976
N-S COMPONENT
40.0
20.0
0.0
-20.0
-40.0
DISPLACEMENT (IN)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
1
TIME (SECONDS)

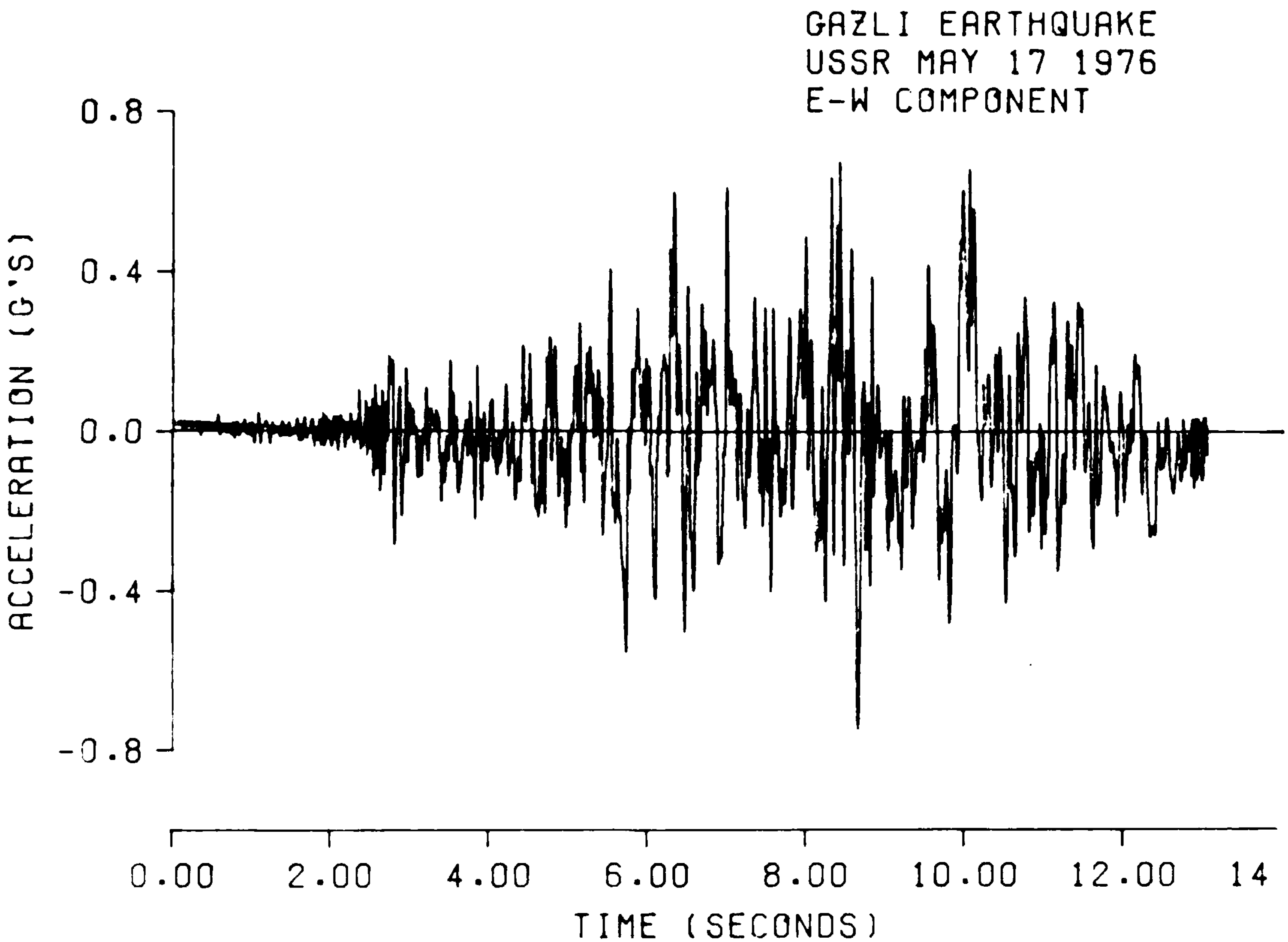


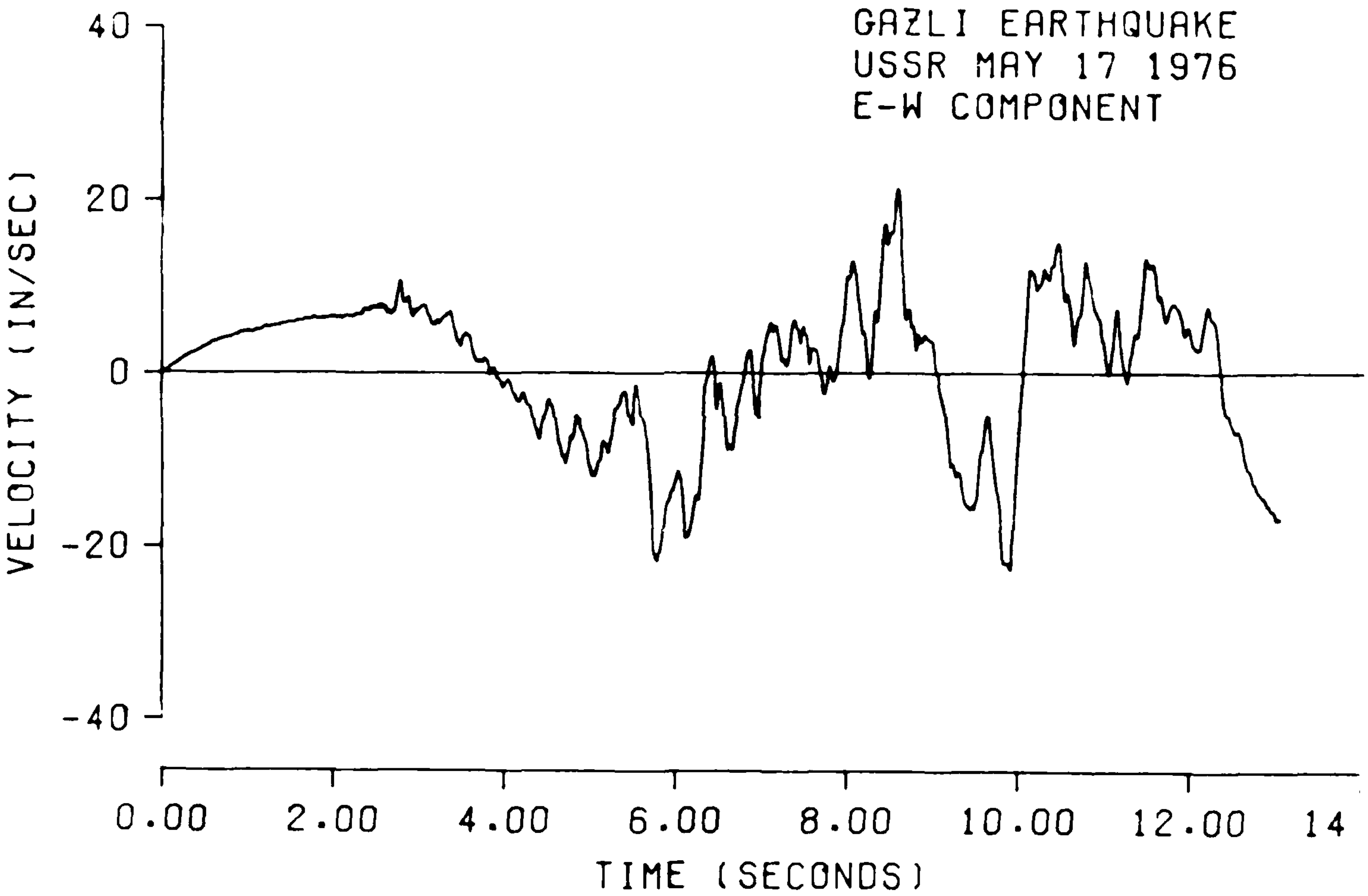
CURVES FOR 0, 2, 5, 10, AND 20 PERCENT DAMPING(C

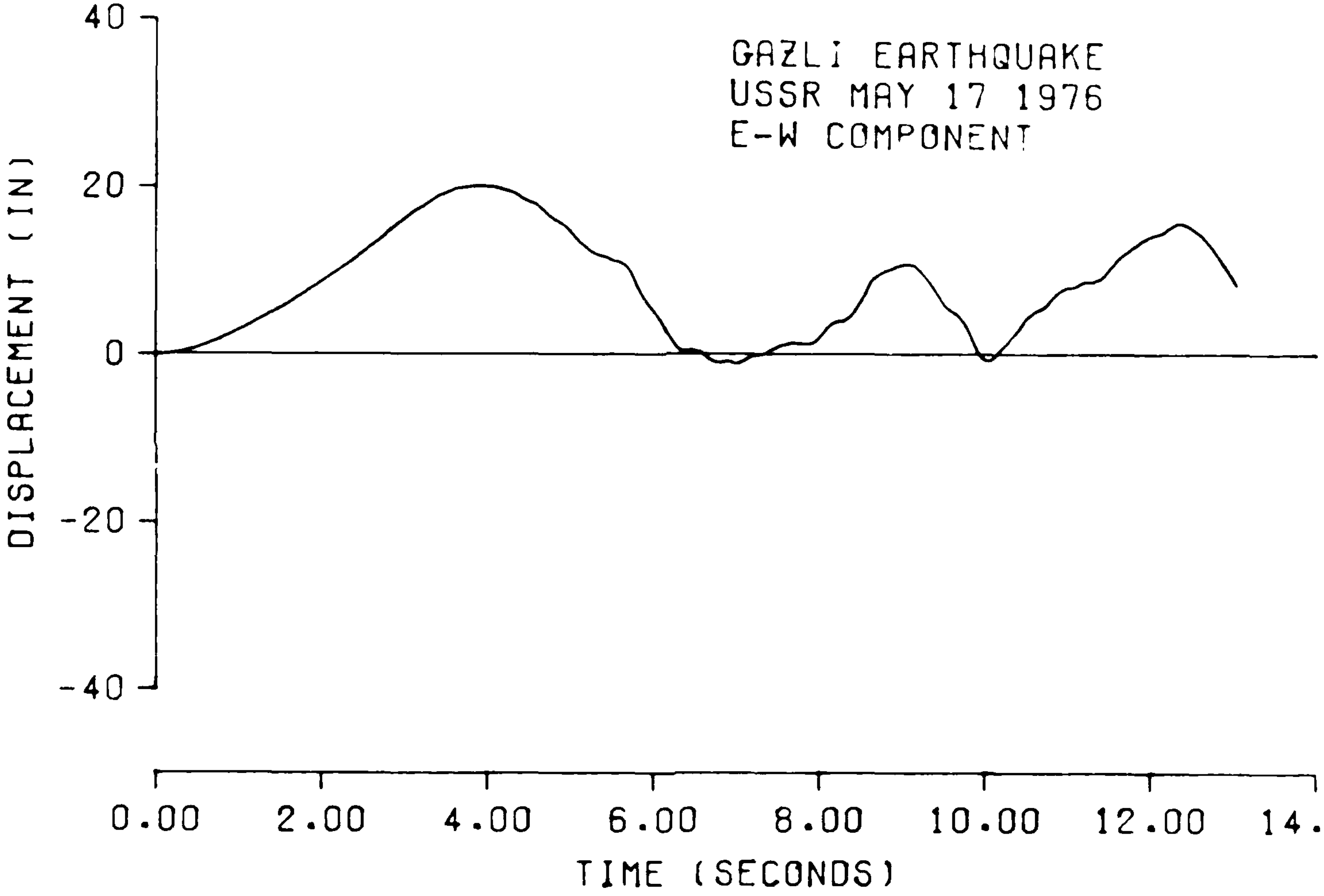

GAZLI EARTHQUAKE
USSR MAY 17 1976
E-W COMPONENT
RELATIVE RESPONSE SPECTRUM
RELATIVE
RESPONSE VELOCITY (IN/SEC)
200
160
120
80
40
0
0.000
2.000
4.000
6.000
8.000
10.000
12.000
PERIOD (SECONDS)
CURVES FOR 0. 2. 5. 10. AND 20 PERCENT DAMPING(C

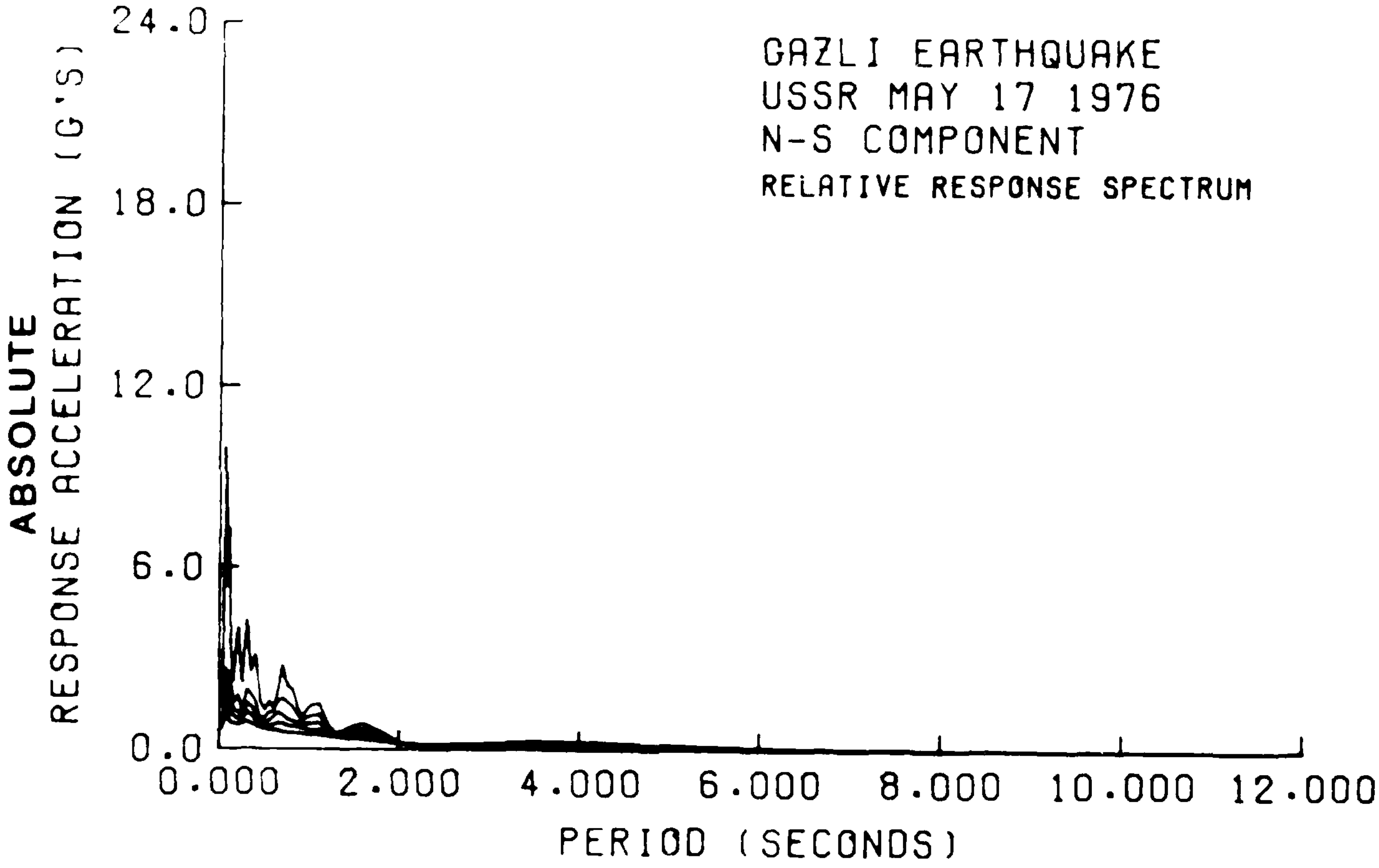


CURVES FOR 0. 2. 5. 10. AND 20 PERCENT DAMPING(C


GAZLI EARTHQUAKE
USSR MAY 17 1976
E-W COMPONENT
ACCELERATION (G'S)
0.8
0.4
0.0
-0.4
-0.8
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14
TIME (SECONDS)


GAZLI EARTHQUAKE
USSR MAY 17 1976
E-W COMPONENT
VELOCITY (IN/SEC)
40
20
0
-20
-40
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14
TIME (SECONDS)


GAZLI EARTHQUAKE
USSR MAY 17 1976
E-W COMPONENT
40
20
0
-20
-40
DISPLACEMENT (IN)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.
TIME (SECONDS)



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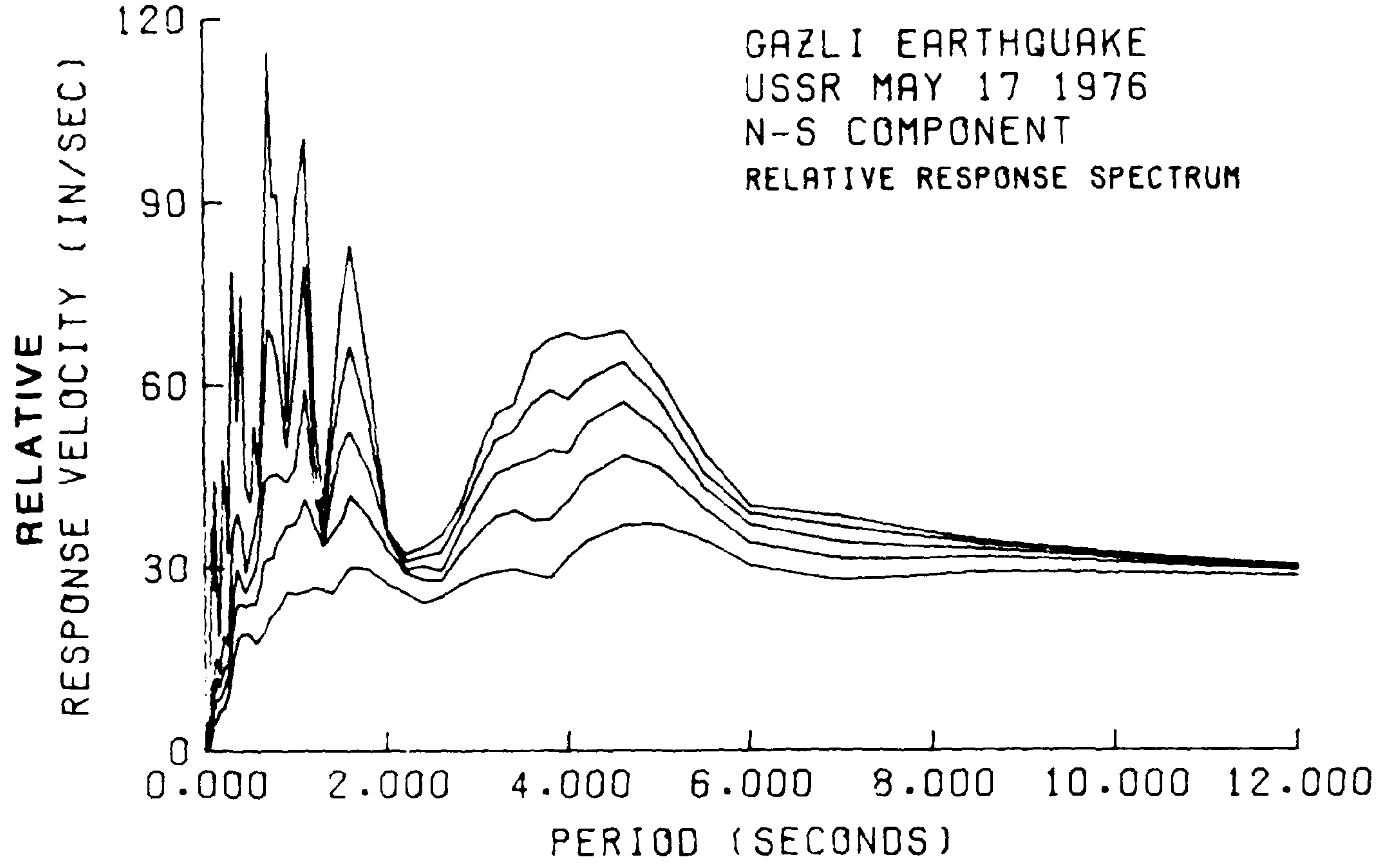

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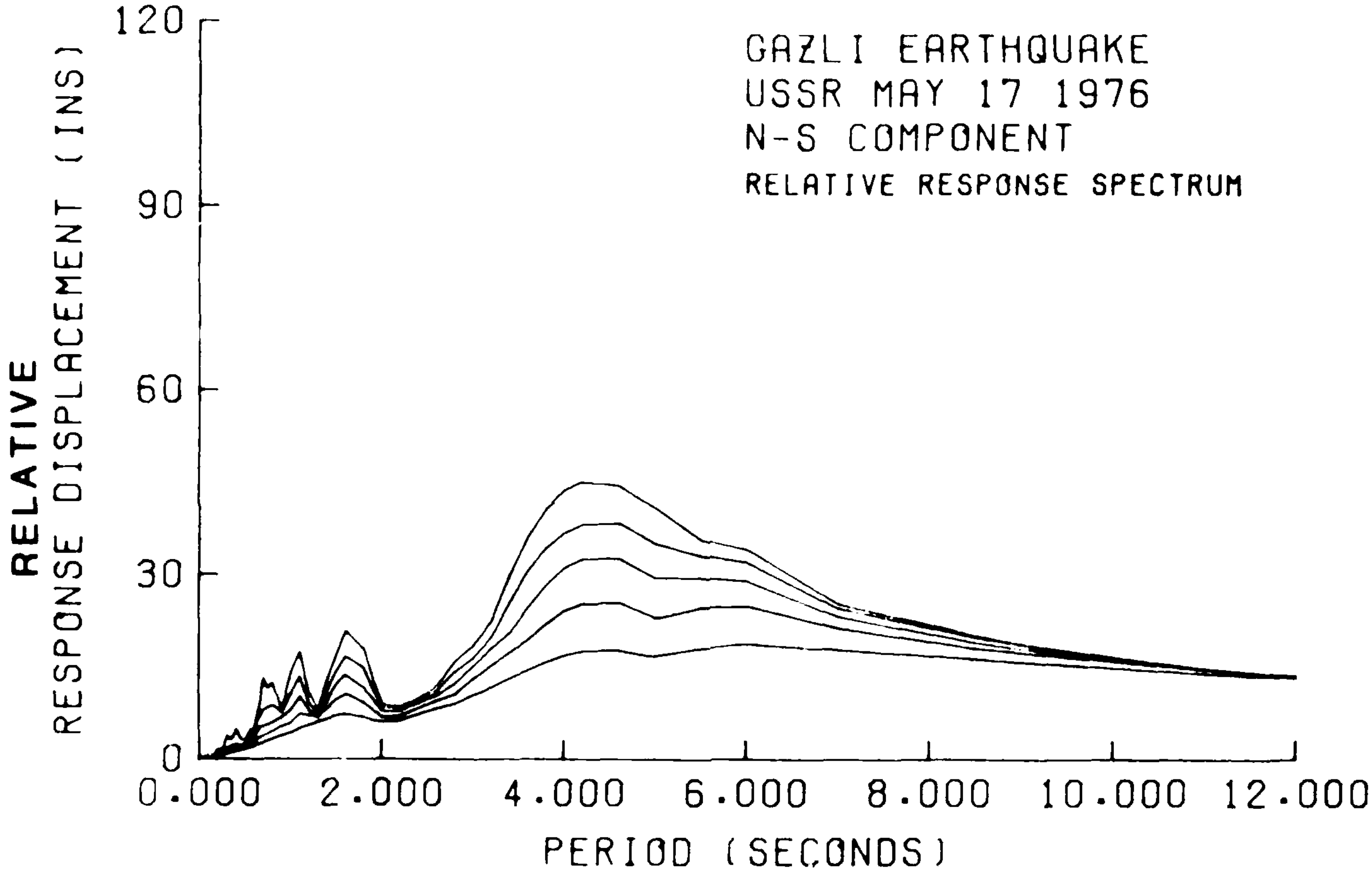

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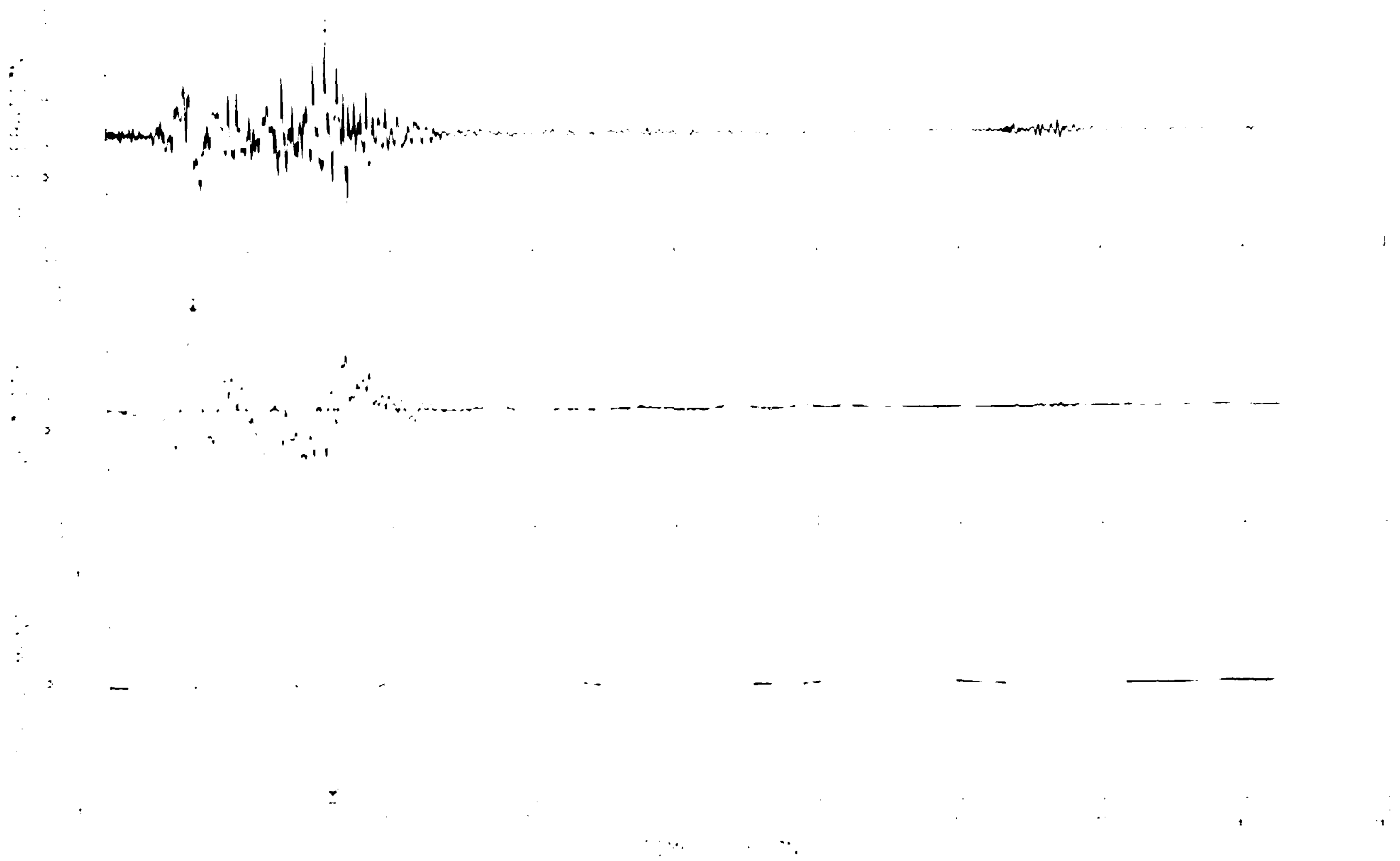
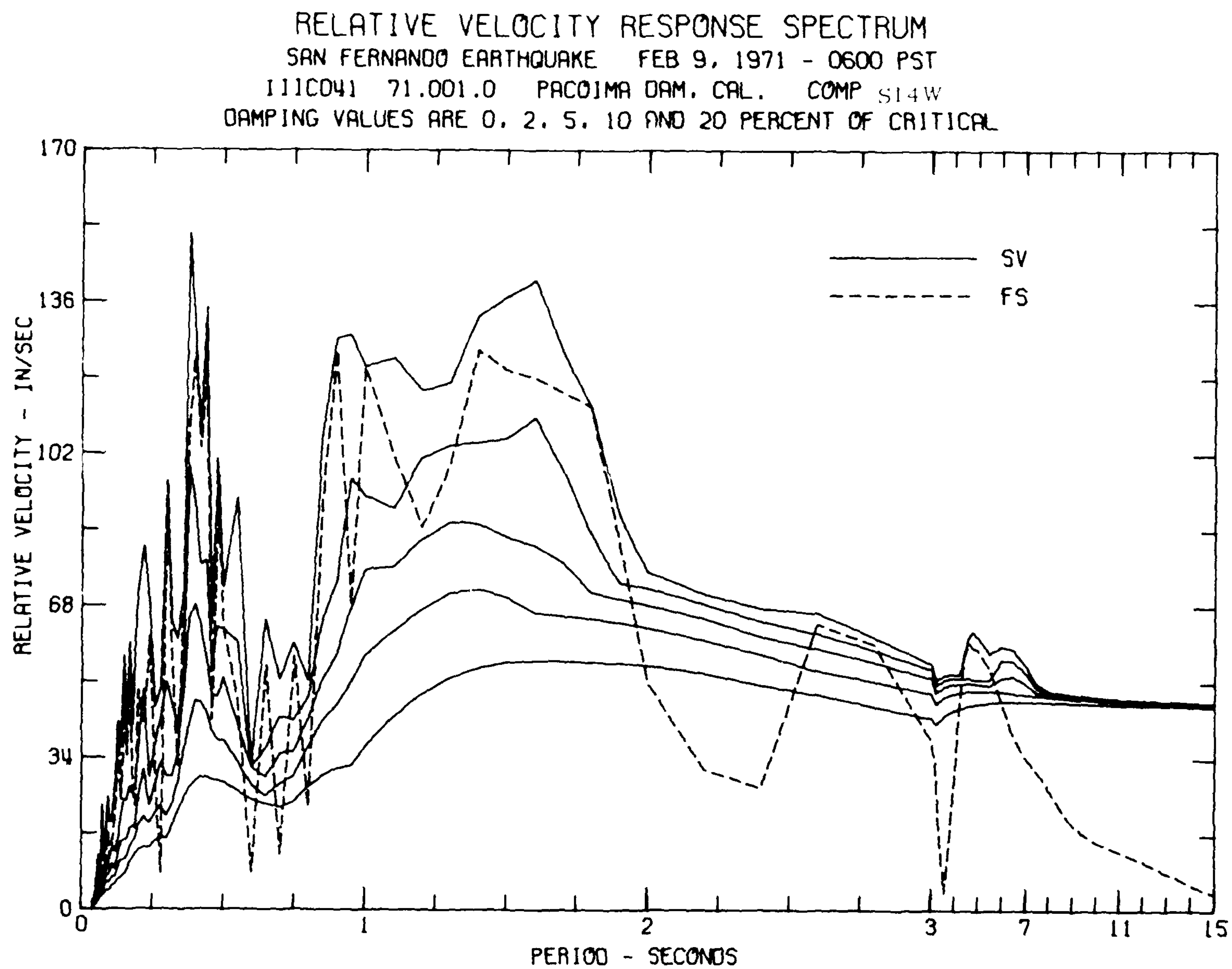
CORRECTED: S14W



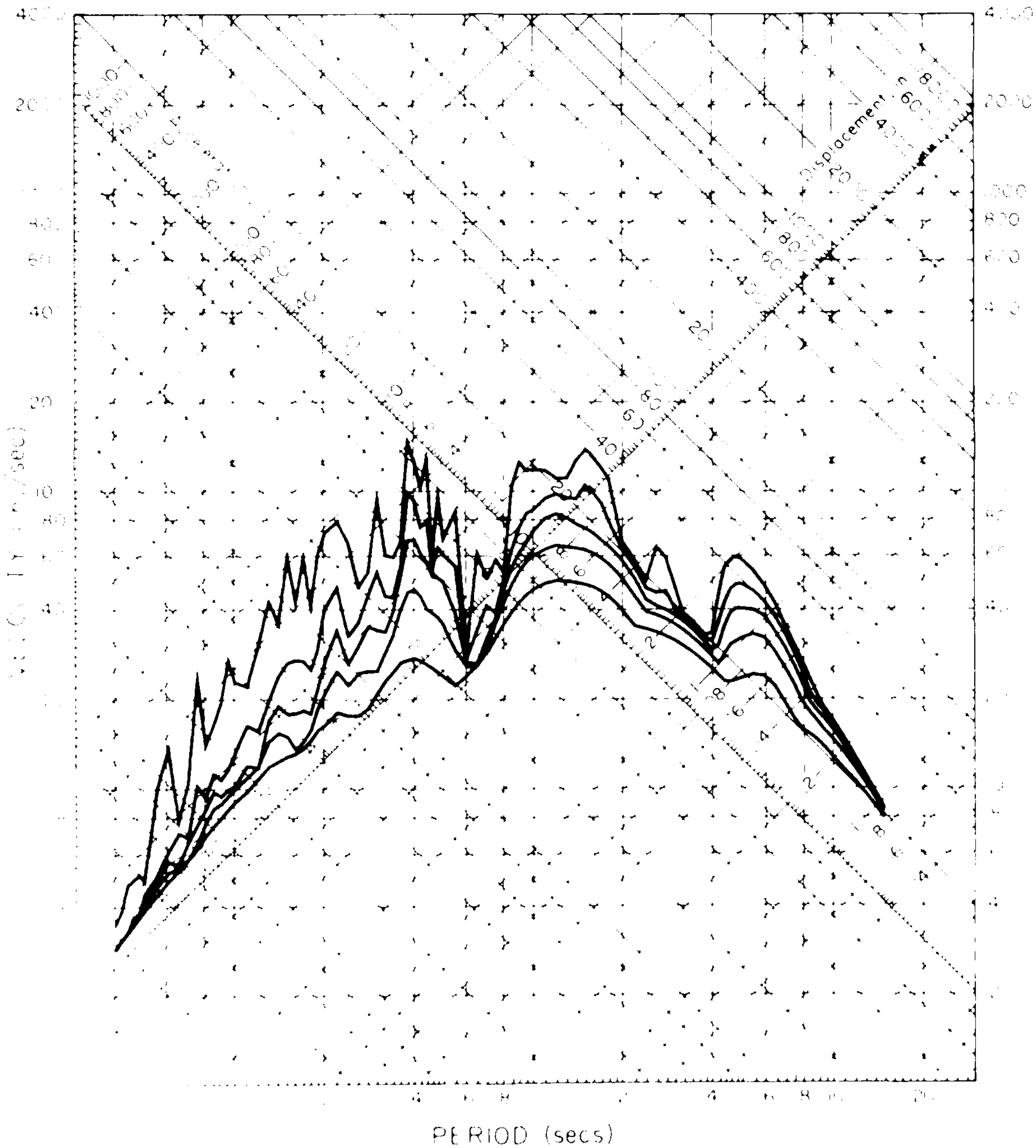

RELATIVE VELOCITY RESPONSE SPECTRUM
SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST
IIIC041 71.001.0 PACOIMA DAM, CAL. COMP S14W
DAMPING VALUES ARE 0, 2, 5, 10 AND 20 PERCENT OF CRITICAL
SV
FS
RELATIVE VELOCITY - IN/SEC
170
136
102
68
34
0
PERIOD - SECONDS
0
1
2
3
7
11
15

RESPONSE SPECTRUM

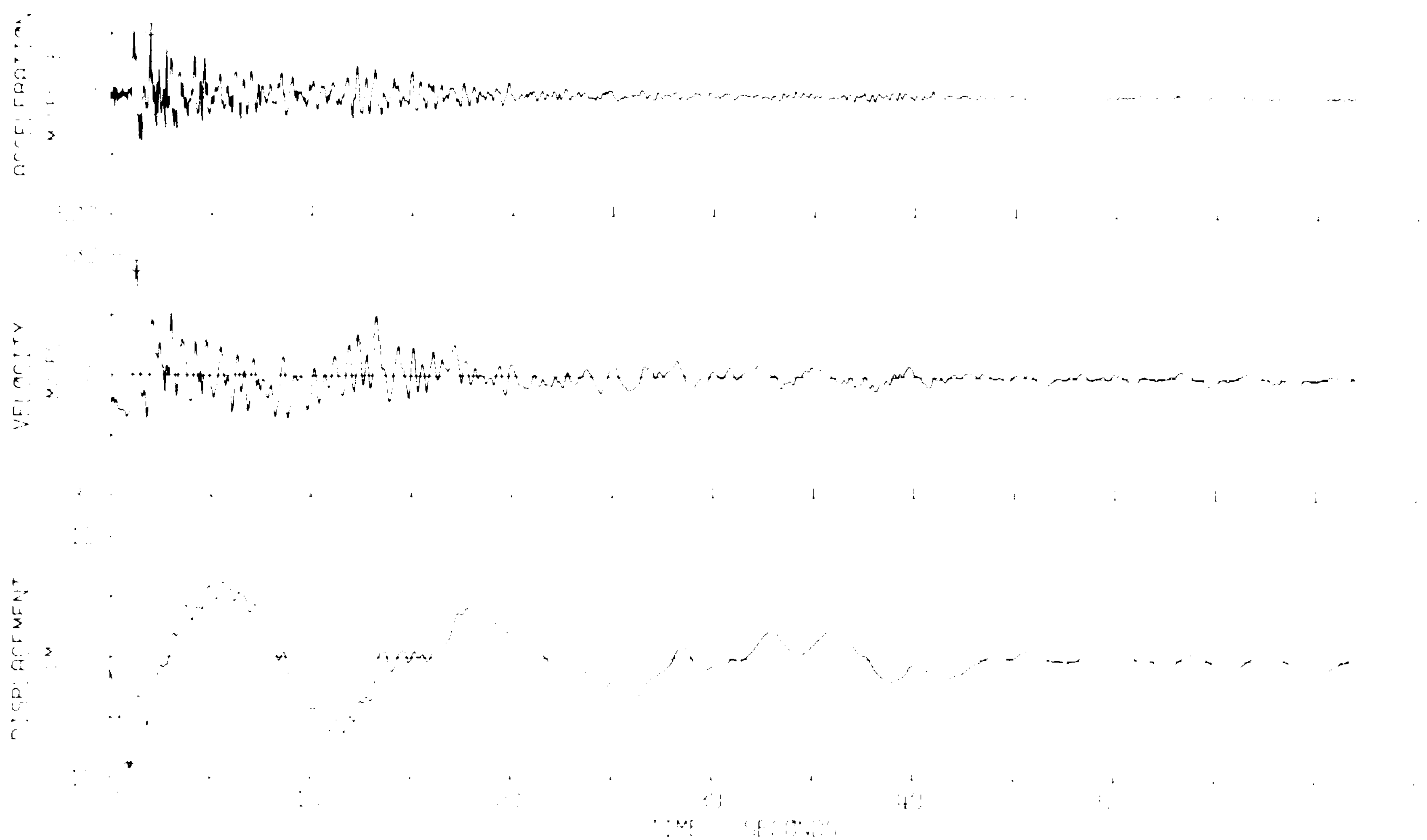
SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST

IIIC041 71.001.0 PACOIMA DAM, CAL. COMP S14W

DAMPING VALUES ARE 0, 2, 5, 10 AND 20 PERCENT OF CRITICAL



SAN FERNANDO EARTHQUAKE

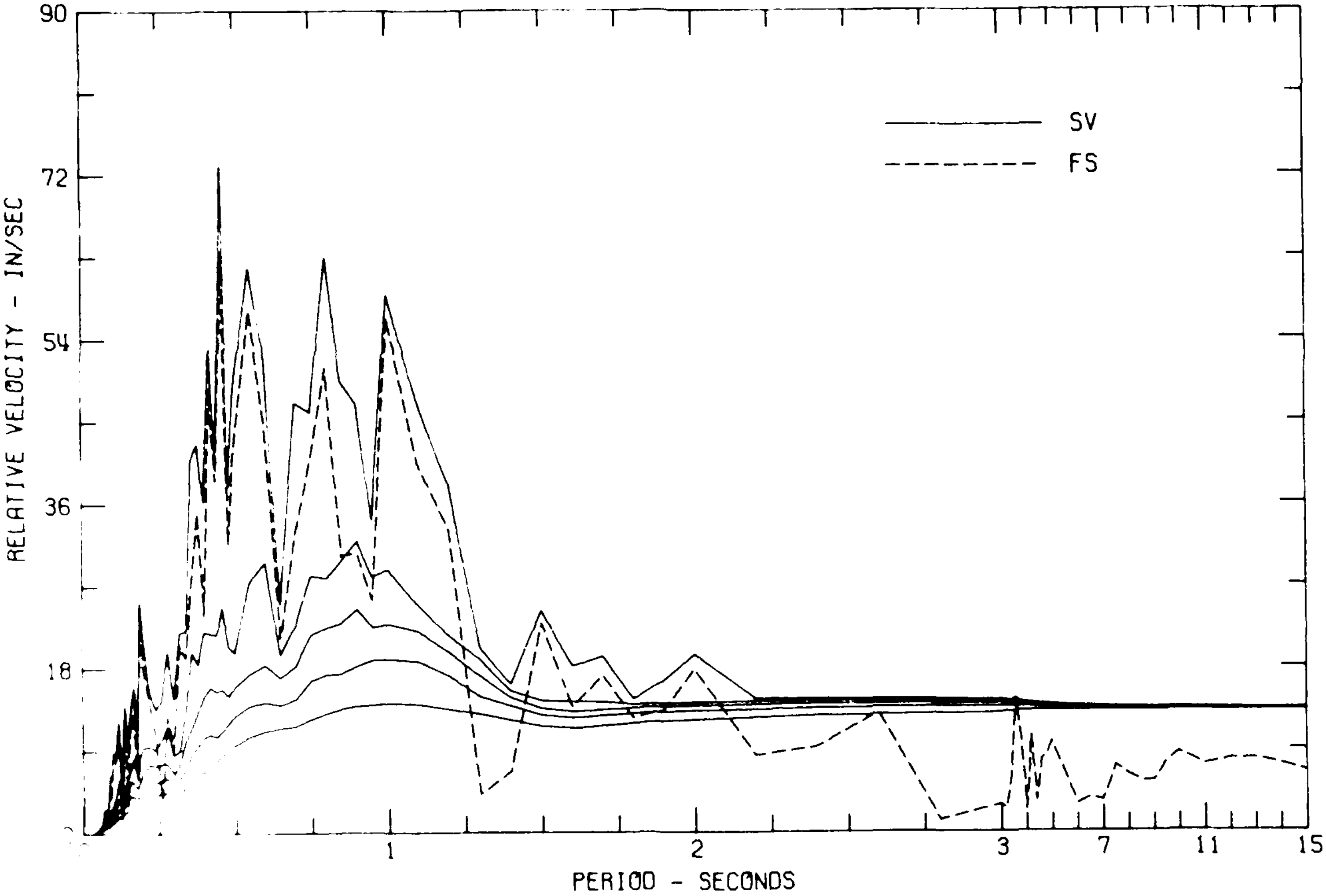


RELATIVE VELOCITY RESPONSE SPECTRUM

SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST

IIID056 71.007.0 CASTAIC OLD RIDGE ROUTE, CAL. COMP N69W

DAMPING VALUES ARE 0, 2, 5, 10 AND 20 PERCENT OF CRITICAL

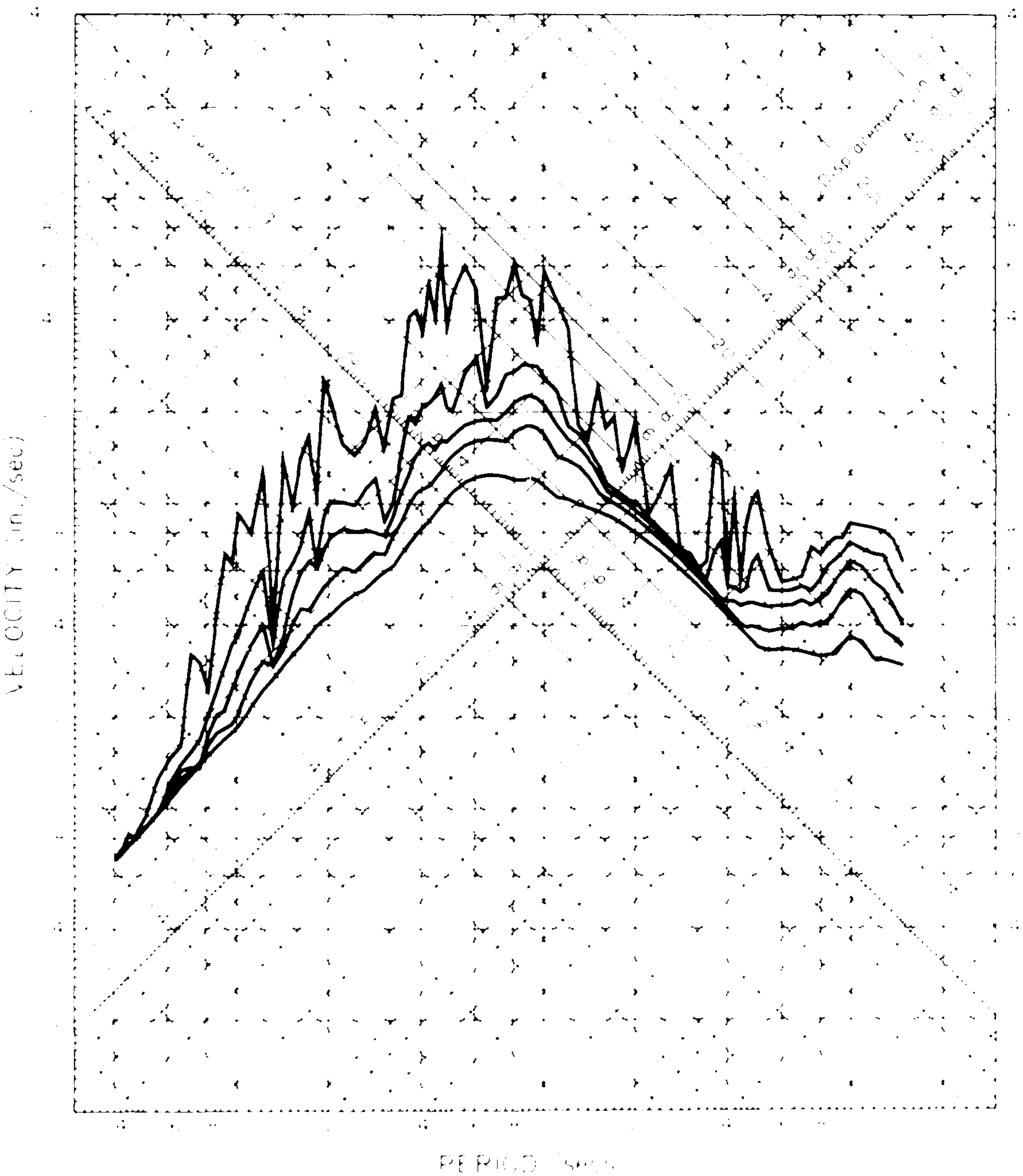


RESPONSE SPECTRUM

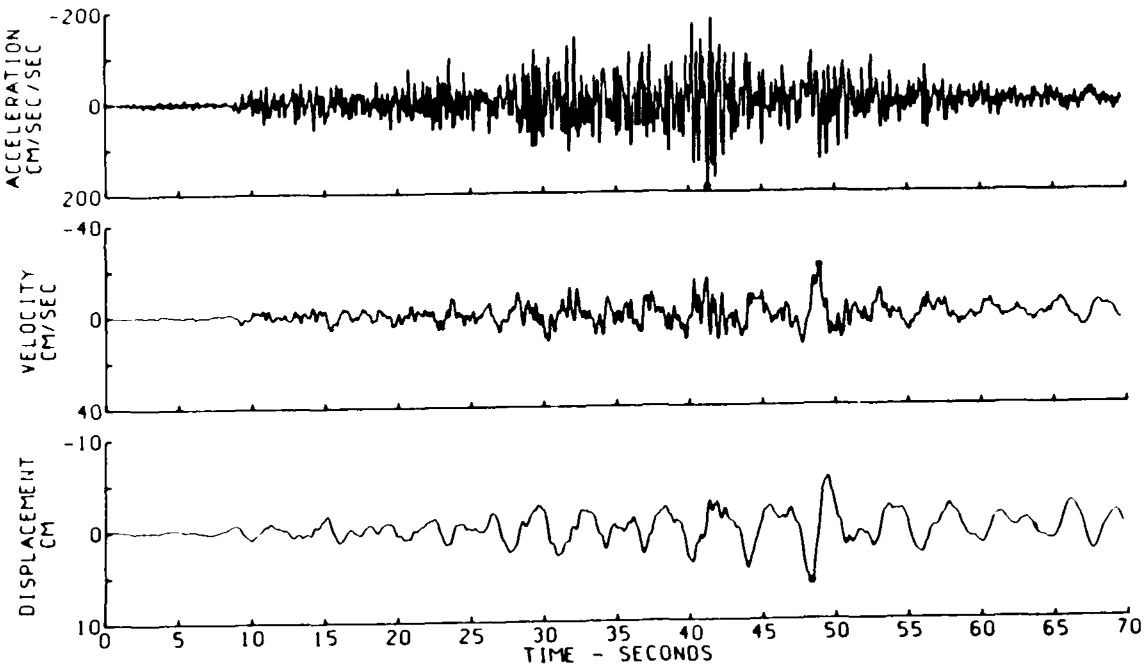
SAN FERNANDO EARTHQUAKE   FEB 9, 1971 - 0600 PST

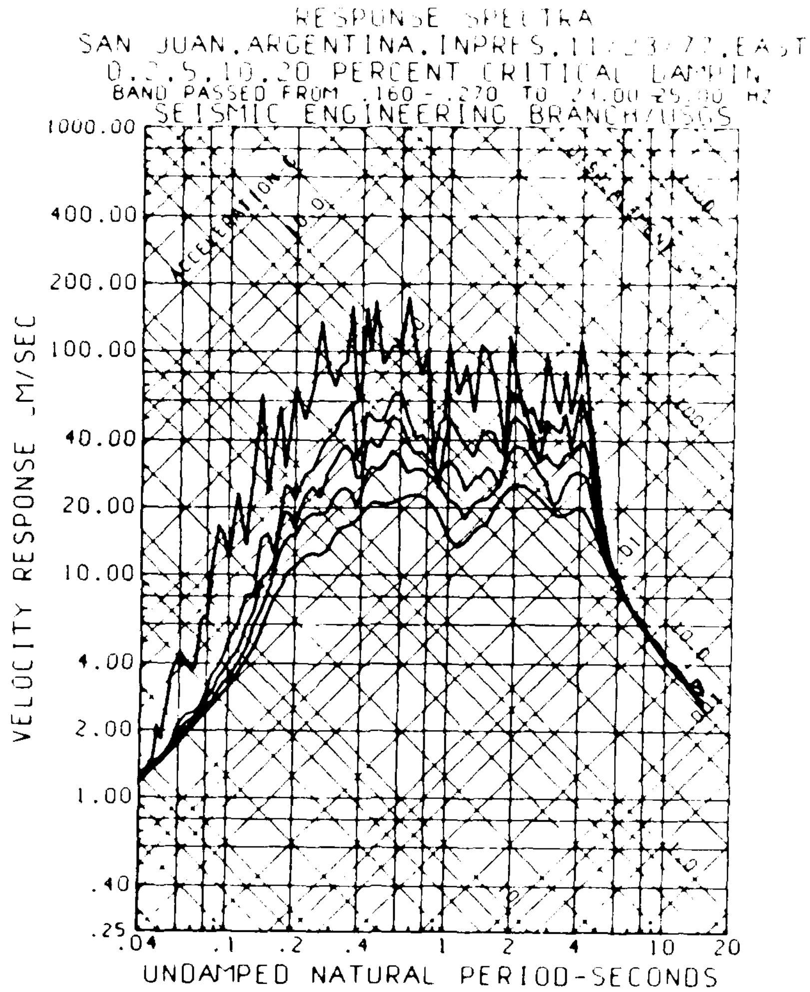
IIID056 71.007.0   CASTAIC OLD RIDGE ROUTE, CAL.   COMP N69W

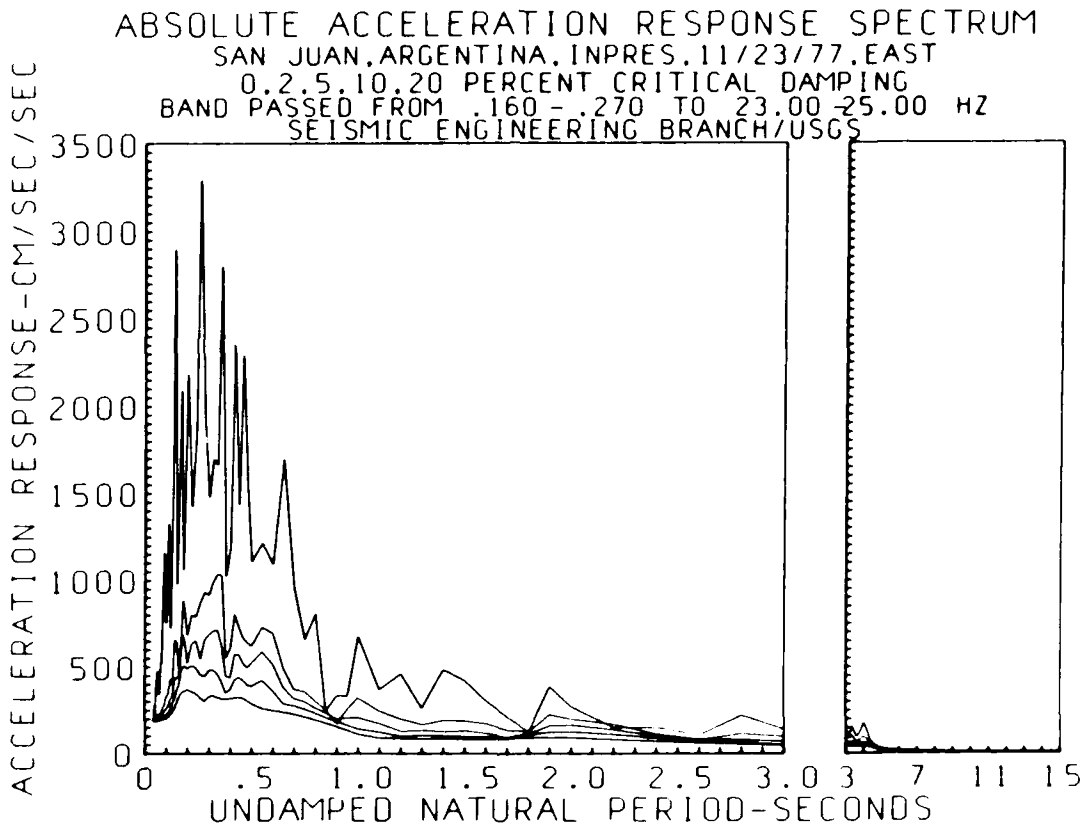
DAMPING VALUES ARE 0, 2, 5, 10 AND 20 PERCENT OF CRITICAL



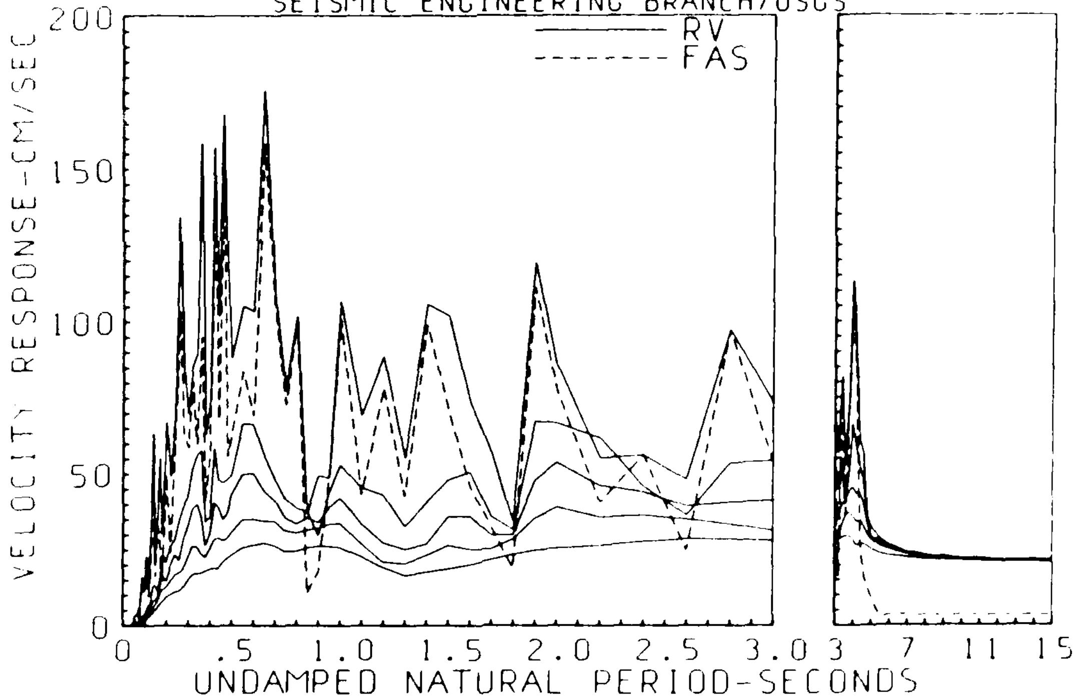
CORRECTED ACCELERATION, VELOCITY, DISPLACEMENT (MB3)
INPRES, ROGER BALET 47 N. EAST COMP
SAN JUAN, ARGENTINA EARTHQUAKE OF NOVEMBER 23, 1977 - 0927 GMT
ACCELEROGRAM IS BAND PASS FILTERED BETWEEN .160 - .270 AND 23.00 - 25.00 CYC/SEC
• PEAK VALUES ACCEL=189.5 CM/SEC/SEC, VELOCITY=-20.59 CM/SEC, DISPL=5.904 CM




RESPONSE SPECTRA
SAN JUAN, ARGENTINA, INPRES
0, 2, 5, 10, 20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .160 - .270 TO
SEISMIC ENGINEERING BRANCH/USGS
1000.00
400.00
200.00
100.00
40.00
20.00
10.00
4.00
2.00
1.00
.40
.25
.04
.1
.2
.4
1
2
4
10
20
ACCELERATION
VELOCITY RESPONSE _M/SEC
UNDAMPED NATURAL PERIOD-SECONDS


ABSOLUTE ACCELERATION RESPONSE SPECTRUM
SAN JUAN,ARGENTINA,INPRES,11/23/77,EAST
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .160 - .270 TO 23.00-25.00 HZ
SEISMIC ENGINEERING BRANCH/USGS
ACCELERATION RESPONSE-CM/SEC/SEC
3500
3000
2500
2000
1500
1000
500
0
0
.5
1.0
1.5
2.0
2.5
3.0
3
7
11
15
UNDAMPED NATURAL PERIOD-SECONDS

RELATIVE VELOCITY RESPONSE SPECTRUM
SAN JUAN, ARGENTINA, INPRES, 11/23/77, EAST
0.2.5.10.20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .160 - .270 TO 23.00 -25.00 HZ
SEISMIC ENGINEERING BRANCH/USGS



END

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DTIC